BRITANNICA GLOBAL GEOGRAPHY SYSTEM

Overview

BGGS Overview

BGGS is the ***Britannica Global Geography System,*** a modular electronic learning system which combines the latest pedagogical approach to geography learning with interactive multi-media materials enabling students and teachers to immerse themselves in exciting geographic investigations. BGGS is made up of the following components:

- *Geographic Inquiry into Global Issues* (GIGI) Student DataBooks
- Teacher's Guides with Overhead Transparencies in a three-ring binder
- Laminated Mini-Atlases to accompany each module
- BGGS CD-ROM with User's Manual
- 3 BGGS Videodiscs with Barcode Guides
- 3 thematic posters

This section of your Teacher's Guide will examine each component and demonstrate how the components work together to facilitate some very exciting geography learning for you and your students!

I. GIGI

Geographic Inquiry into Global Issues (GIGI) is the foundation of the BGGS. GIGI is a series of modules developed at the Center for Geographic Education at the University of Colorado at Boulder. The modules are independent of one another and can be presented in any order. They use an inquiry approach and are organized around ten world regions:

South Asia
Southeast Asia
Japan
Former Soviet Union
East Asia
Australia/New Zealand/Pacific
North Africa/Southwest Asia
Africa-South of the Sahara
Latin America
Europe

Each GIGI module is centered around a particular question, such as "Why are people in the world hungry?" and "Is freedom of movement a basic human right?" The lead question is explored in one region of the world, then, in most modules, in a second region, before being investigated in North America.

The modules can be used in geography classes, or selected modules can be used in other courses, such as Earth Science, Global Studies, or Economics. Twelve modules constitute ample material for a full year's geography course. Each module is accompanied by sets of laminated mini-atlases which students can write on with dry-erase markers (provided by the teacher), then wipe clean to be re-used by the next class. This activity works well with cooperative groups of students.

Each module comprises a Teacher's Guide in a three-ring binder which includes Handouts and Activity masters for duplication and Overhead Transparencies; twenty-five Student DataBooks (additional Student DataBooks available) and the Mini-Atlases all packaged in a sturdy box suitable for storage when the class moves on to the next module. Since the Student DataBooks are soft-covered three-hole punched, non-consumable books, we recommend that each student have a binder to protect them. BGGS binders are available from Britannica, or you might ask each student to obtain one at the beginning of the course to keep the books in good condition for the next group of students that will use them. As the class completes a module, you can collect the Student DataBooks, place them in their storage box, and distribute the next module's DataBook to be placed in the student's binder.

GIGI print materials are organized in a unique fashion. The Teacher's Guide explains procedures to use in presenting the material found in the GIGI Student DataBook. Miniature layouts of student pages show the teacher how many pages of student material correspond with a given Teacher's Guide page. The Teacher's Guide includes Activities and Handouts to be copied and passed out to the class and Overhead Transparencies to enhance each lesson. All of a module's Activities, Handouts, and Overheads are located behind the third tab divider in each Teacher's Guide.

The teacher needs to become familiar in advance with both Teacher and Student material in order to effectively engage the class in meaningful geographic inquiries. There is a comprehensive "Memo to the Teacher from the GIGI Staff" in each Teacher's Guide which explains in detail the goals and principles behind the inquiry approach to geography learning.

The electronic components of the ***Britannica Global Geography System*** further empower students and teachers alike to engage in meaningful investigations. They are explained in detail in the following section.

II. BGGS CD-ROM

The **BGGS CD-ROM** is a resource manager and reference tool designed to help both teachers and students get maximum impact from the ***Britannica Global Geography System.*** This CD-ROM contains the text of the GIGI Student DataBooks in both Spanish and English, as well as Britannica's innovative geography reference program Geopedia™ all on a single disk. Here are some of the ways you and your class can use this software:

- When preparing to teach a module, you can access the GIGI Student DataBook on the CD to find which other elements of the BGGS are keyed to that lesson. For example, if you are teaching Lesson 3 in the Population and Resources module (What is overpopulation and how is it distributed?), accessing that lesson on the CD-ROM will reveal that there is one clip on the *Economic Development* videodisc called "Population/Wealth Correlation." With this information, you can plan when to reserve your department's videodisc player to preview the clip and show it to your class.

Furthermore, you will discover that there is one GIGI mini-atlas activity related to this lesson, five articles in the Geopedia database, ten entries in

Geopedia's World Data, five maps in the Geopedia Atlas, and five learning activities in the Geopedia BrainTeasers. You may want to assign each student or small group of students a research project using these extra resources to be done over the course of the module, or you can create a set of questions which the students must complete using the information found in Geopedia.

These activities can serve as a performance-based assessment of what students have learned in studying each module.

Since many schools have a limited number of computers with CD-ROM drives available, you may wish to devise a rotating schedule or sign-up system to ensure that each student has a chance to get at the BGGS CD-ROM. If it takes 15 class periods for a class of twenty-five students to do one module, students working in pairs can each have one turn at the computer if they schedule their time at the outset of the module. Using the CD-ROM's resource managing capability, you will have a very good sense of what resources you have at your disposal and how to make the most of them.

- All GIGI lessons are indexed by word and by key topic. If your class is studying food shortages in the Hunger module, you can key in the word hunger, and immediately learn where else in the GIGI modules this word or key topic appears. You can go directly to those occurrences in the text. You will also be directed to appropriate Geopedia references and Brain Teaser activities. Figures, Maps and Tables from GIGI print modules do not appear in the CD-ROM. However, the caption describing each of them is part of the online text.
- If Spanish is the primary language of your students, GIGI lessons can be accessed and printed out in Spanish from the BGGS CD-ROM. The BGGS Videodiscs have a Spanish soundtrack as well.

III. BGGS Videodiscs

More than ever before, today's students are visual learners. The GIGI modules explore issues and regions of the world with which many students are unfamiliar. With this in mind, we have produced three videodiscs, one to correspond to each of three major strands we have identified in GIGI: *Earth's Environment and Society; Economic Development;* and *Global Political and Cultural Change.*

These videodiscs, with English and Spanish soundtracks, can take you and your class to the parts of the world you are investigating with the wave of a barcode wand. Your class will hear how Amazon native peoples feel about the exploitation of the tropical rain forests where they live, witness the eruption of a volcano, and see first-hand the environmental disasters human beings have brought about.

The Barcode Guide which accompanies each disc enables you to access with a light pen or barcode reader, segments which pertain to the lesson being investigated. The Guide includes barcodes in both English and Spanish. Teachers can use the segments to enrich lessons, and students can make use of segments to enhance a report or group presentation.

There is a full-color poster to accompany each videodisc cluster which engages the students by asking "How do these images connect to you?" The posters can provide a colorful springboard for classroom discussion.

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BRITANNICA GLOBAL GEOGRAPHY SYSTEM

GIGI

Geographic Inquiry into Global Issues

Sustainable Agriculture

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Teacher's Guide

Regional Case Study
Southeast Asia

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Contents

Memo to the Teacher from the GIGI Staff

You have in your hands the GIGI Teacher's Guide. Teaching with GIGI is a departure from teaching with a conventional textbook. By taking the time to study this memo—about 30 minutes—you will gain a good understanding of the kind of teaching that's needed to be successful with GIGI. We hope you have a rewarding and enjoyable experience!

Goals

The three major goals of *Geographic Inquiry into Global Issues* (GIGI) are to help you teach your students the following:

1. Responsible citizenship
2. Geographic knowledge, skills, and perspectives
3. Critical and reflective thinking

We believe you can accomplish these goals as well as others by teaching real-world issues. GIGI presents these issues with an inquiry approach, using the information, concepts, skills, and perspectives of geography.

GIGI and the Britannica Global Geography System

GIGI offers you two instructional modules for each of ten world regions (Figure 1 on pages vi and vii). There is no necessary sequence of modules; each one is independent, so you can use them in any order you wish or put together smaller clusters of modules to fit your needs. A leading question frames the issue of each module, and student inquiry proceeds through a sequence of lessons, each of which requires one or more daily periods of class time.

Color photographs at the beginning and end of each Student DataBook graphically illustrate the topic under inquiry.

Modules typically begin with a broad introduction to the global issue. Then, a major case study of three to four lessons examines the issue in a real place within the selected world region. Students also explore, usually in a single lesson, a comparative case study in a *different* region, which gives a variant of the issue and a sense of its global nature. Modules also bring the students "back home" to focus on the issue as it may appear in the United States or Canada. We do this because although North America is not one of the 10 GIGI regions, frequent comparisons to North America throughout each module achieve additional instruction on this "home region."

Each GIGI module requires from two to three weeks of teaching time (10 to 15 class periods of 50 minutes) and contains a Student DataBook, Teacher's Guide, and Mini-Atlas. These GIGI print materials are at the heart of the Britannica Global Geography System (BGGS), which extends and enhances the inquiry approach to real-world issues with a CD-ROM and three videodiscs.

The BGGS CD-ROM puts the text of the GIGI Student DataBooks on line in both English and Spanish, then enables both teacher and students to search the text by lesson, key topic, or word to find the resources in the system that will enhance each. Geopedia™, Britannica's multimedia geography program, is provided in the CD-ROM for follow-up research. It features an atlas with more than 1,000 new maps, an encyclopedia with more than 1,200 geography-related articles, statistical information on every country from Britannica World Data Annual, a chartmaker for creating charts and graphs, a selection of video clips exploring cities and regions, and an electronic notepad allowing teachers and students to clip and edit text right on the screen.

Three videodiscs, designed to electronically transport students to the regions of the world where GIGI case studies are focused, are another part of the BGGS. The discs emphasize three major strands of the GIGI investigations: *Earth's Environment and Society, Economic Development,* and *Global Political and Cultural Change.* Each videodisc has two soundtracks, English and Spanish, and is accompanied by a Barcode Guide that enables teachers and students to access the segments that accompany the GIGI lesson with a wave of the barcode reader. A poster accompanies each videodisc to reinforce the connnections between your students and the issue being studied.

A full explanation of the Britannica Global Geography System components and how they work together is located in the BGGS overview in the front section of this Teacher's Guide.

Geographic Inquiry into Global Issues (GIGI)

Issues, Leading Questions, and Case Study Locations

South Asia	**Population and Resources** *How does population growth affect resource availability?* Bangladesh (Haiti)	**Religious Conflict*** *Where do religious differences contribute to conflict?* Kashmir (Northern Ireland)
Southeast Asia	**Sustainable Agriculture** *How can the world achieve sustainable agriculture?* Malaysia (Cameroon, Western United States)	**Human Rights** *How is freedom of movement a basic human right?* Cambodia (Cuba, United States)
Japan	**Global Economy*** *How does trade shape the global economy?* Japan (Colombia, United States)	**Natural Hazards** *Why do the effects of natural hazards vary from place to place?* Japan (Bangladesh, United States)
Former Soviet Union	**Diversity and Nationalism*** *How do nations cope with cultural diversity?* Commonwealth of Independent States (Brazil, United States)	**Environmental Pollution** *What are the effects of severe environmental pollution?* Aral Sea (Madagascar, United States)
East Asia	**Population Growth*** *How is population growth to be managed?* China (United States)	**Political Change** *How does political change affect peoples and places?* Hong Kong (South Korea, Taiwan, Singapore, Canada)

* Under development

Figure 1 Matrix showing GIGI modules. Geographic issues are in bold and leading questions are in italics. Major case study locations are followed by comparison examples in parentheses.

Geographic Inquiry into Global Issues (GIGI)
Issues, Leading Questions, and Case Study Locations

Australia/ New Zealand/ Pacific	**Global Climate Change** *What could happen if global warming occurs?* Australia and New Zealand (Developing Countries, U.S. Gulf Coast)	**Interdependence*** *What are the causes and effects of global interdependence?* Australia (Falkland Islands, United States)
North Africa/ Southwest Asia	**Oil and Society*** *How have oil riches changed nations?* Saudi Arabia (Venezuela, Alaska)	**Hunger** *Why are people hungry?* Sudan (India, Canada)
Africa—south of the Sahara	**Building New Nations*** *How are nation-states built?* Nigeria (South Africa, Canada)	**Infant and Child Mortality** *Why do so many children suffer from poor health?* Central Africa (United States)
Latin America	**Urban Growth** *What are the causes and effects of rapid urbanization and urban growth?* Mexico (United States)	**Development** *How does development affect peoples and places?* Amazonia (Eastern Europe, U.S. Tennessee Valley)
Europe	**Regional Integration*** *What are the advantages of and barriers to regional integration?* Europe (United States, Mexico, Canada)	**Waste Management** *Why is waste management both a local and global concern?* Western Europe (Japan, United States)

* Under development

Figure 1 (continued)

The **Student DataBook** contains the following features:
- Memo to the Student from the GIGI Staff
- An overview of the key questions and places explored in the module
- Lesson objectives
- Data presented in a variety of forms, including text, maps, graphs, tables, photographs, and cartoons
- Questions
- Glossary
- References

Students are not expected to learn the GIGI curriculum through the Student DataBook alone. Rather, they derive meaning from the DataBook when you use the Teacher's Guide to work through the curriculum with them. You may want to explain this process to students. Point out that you will be directing them to carry out various activities that are not specified in their text but are important in the sequence of learning.

Prior to teaching the first lesson, be sure students read the "Memo to the Student from the GIGI Staff" and the two-page overview, which gives the module's objectives in question form. Point out the Glossary and encourage its use as you work through the module, noting that glossary words are listed at the beginning of each lesson. So that students will know what they are expected to learn, they need to read carefully and understand the objectives listed at the beginning of each lesson.

This **Teacher's Guide** contains the following sections:
- Preparing to Teach This Module, a synopsis of the module's leading question, themes, and activities
- Module Objectives
- Number of Days Required to Teach the Module
- Suggestions for Teacher Reading
- Extension Activities and Resources

Most lessons include the following sections:
- Time Required
- Materials Needed
- Glossary Words
- Getting Started (suggested anticipatory sets)
- Procedures (for group and individual work)
- Modifications for older or younger students (in a different type face, printed in color)
- Questions and Answers (shown in tinted boxes)
- For Further Inquiry (suggestions for extensions and/or assessments)

- Masters of Overhead Transparencies and Activity masters and keys (located at the back of the Teacher's Guide)

Each module has its own accompanying **Mini-Atlas,** which provides four-color maps designed especially for use with that module. The Teacher's Guide explains how to use these maps. No additional atlases are required to teach the module, but large wall maps are highly recommended for your classroom. In addition to the maps in the Mini-Atlas, you will find numerous maps in the Student DataBook.

Intended Grade Levels

We believe GIGI enables you to probe global issues in various degrees of depth. This allows for the modules' use both over several grade levels (7–12) and over varying lengths of time at a grade level. The Teacher's Guides suggest alternatives for modifying instruction for different grade levels where appropriate. The reading level varies within each module: The Student DataBooks are approximately at grade 9 level, but some extracts from other sources are more challenging. These extracts are important because they show students that many people have contributed to the data, but younger students may need more time and help to understand them. The Teacher's Guides also include extension activities and resources that can maximize the grade-level flexibility of each module. Using the visuals included in the BGGS videodiscs and the activities built into the CD-ROM, you can further tailor instruction to your students. Obviously, you will determine whether particular lessons suit your students' abilities. When a range of required teaching time is given for a module, for example, 10 to 12 days, the greater amount of time should be planned for younger students. If you believe a lesson might be too difficult for your students, eliminate or simplify it. Rarely will the elimination of a lesson render a module ineffective. On the other hand, try to utilize the suggested extensions if the lesson does not adequately challenge your students.

Issues-Based Geographic Inquiry

In order to foster active learning and higher-level thinking, GIGI stresses issues-based geographic inquiry. Inquiry is essentially the method of science and of good detective work: It poses questions and proposes answers about the real world and it tests its answers with real data. Students do this with GIGI. Because this approach may be different from what students are familiar with, you may wish to prepare them by describing the process and its connection to the real world. Also, their reading and discussion of the "Memo to the Student from the GIGI Staff" will help them understand the inquiry approach. GIGI is based on Frances Slater's inquiry activity planning model (1993). To reach GIGI's goals, your students study specific global issues by pursuing answers to geographic questions (Figure 2). They answer these questions by analyzing and evaluating data, using geographic methods and skills. This "doing geography" approach leads to significant outcomes in knowledge, skills, and perspectives. The progression from questions to generalizations "is crucial as a structure for activity planning and as a strategy for developing meaning and understanding. Meaning and understanding define the process of tying little factual knots of information into bigger general knots so that geography begins to make sense, not as a heap of isolated facts but as a network of *ideas and procedures*" (Slater 1993, page 60).

In truly free inquiry, students work independently, but with GIGI posing questions and providing data, you and your students explore the issues together. This approach supports and encourages your students in learning geography.

By using issues-based inquiry, you promote the development of a critical perspective in your students. They learn the habits of critical and reflective thinking. Multiple and opposing positions are inherent

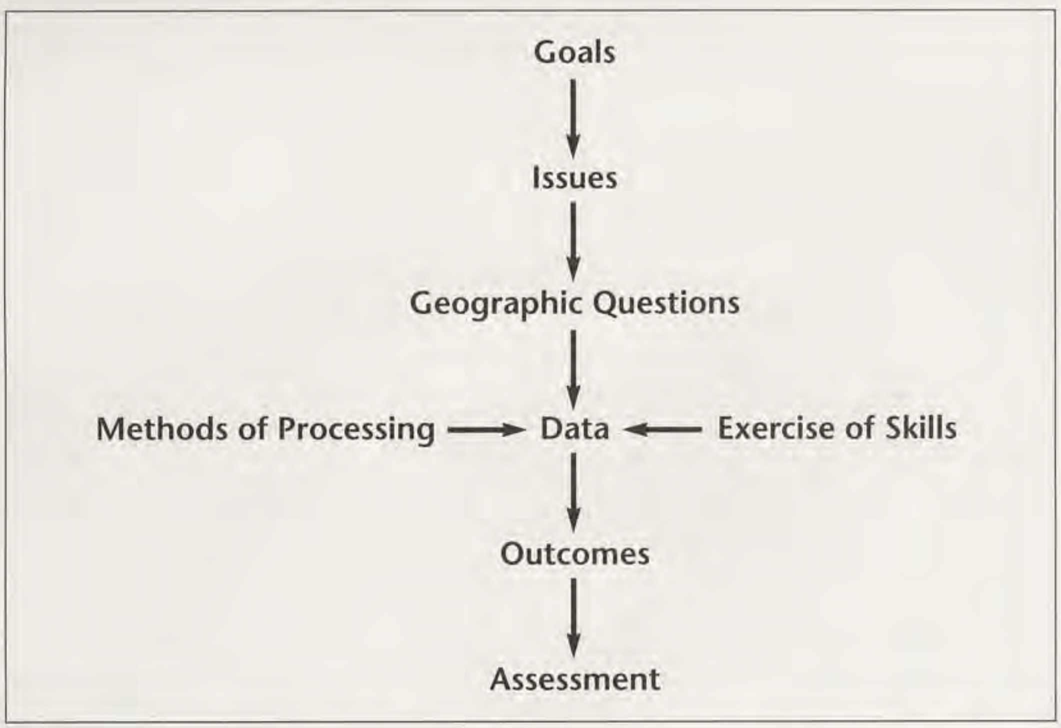

Figure 2 GIGI's model for issues-based geographic inquiry (after Slater 1993).

in these issues. Facts can be used to support different points of view. This is the context in which the habits of the critical perspective can develop, and *interpretation* is the key activity. With GIGI you foster these habits and abilities as you help your students interpret data guided by hypotheses, propositions, arguments, or questions.

An essential element of data-based, issues-oriented inquiry is to challenge your students by giving them opportunities to

- raise new questions,
- question the quality of the data,
- seek more useful or current data,
- articulate relationships they perceive,
- explain their processes of investigation, and
- defend their positions, decisions, and solutions.

Why These Issues Were Chosen

In planning GIGI, we sought timeless issues that are truly global in scope and that are of special concern to geographers. In this way, GIGI fosters what the National Geography Standards calls "the geographically informed person" needed by modern global citizenry (Geography Education Standards Project 1994).

The major case study, chosen to give solid grounding to the issue, is focused on a region where the issue is clearly expressed. The secondary case studies, based in other regions including the United States and Canada, show the *global* scope of the issue.

It is important to stress that, although GIGI contains a wide selection of case studies in all major regions (Figure 1) as well as frequent references to the global distribution of many geographic phenomena, GIGI is not a traditional regional geography. It does not attempt to provide basic geographic information for each region, such as one finds in traditional regional geography textbooks. In teaching a GIGI module, it is important to keep the emphasis on the issue and not get distracted with extraneous regional information.

Role of Questions

Each GIGI module is divided into six to eight lessons, each titled by a question; subquestions head individual sections of the lessons. Questions guide inquiry in order to merge the process of investigation with the drawing of conclusions. Directly linking questions and answers helps achieve an intellectually satisfying understanding of a problem (Slater 1993). When students are asked to learn only conclusions without learning how they are drawn, we perpetuate the tradition of an answer-centered education bereft of higher-level thinking. Therefore, it is important that students understand they are not always expected to answer the questions when they first appear, but rather to keep them in mind as guides when they are reading or discussing.

GIGI asks both convergent and divergent questions, trying to reach a balance between the two. Supplement the questions in GIGI by asking your students many more of the types of questions suggested by Slater (1993). These are questions that encourage

- recall,
- classification and ordering,
- the use of data to draw conclusions,
- awareness of the limitations of data or of evaluation of data, and
- awareness of the processes of reasoning used.

According to the National Geography Standards, the "geographically informed person applies a comprehensive spatial view of the world to life situations" (Geography Education Standards Project 1994). In order to foster such a view of the world, GIGI asks *geographic* questions that ask where things are and why. By asking such geographic questions and by having students learn to ask them, you will reinforce GIGI's approach. A good question to begin with is: Where is this issue located? Then proceed to questions such as the following:

- Why does it take place there?
- How and why does this issue affect the people in this place?
- In what other places do people confront this issue?
- How and why are these places related?
- What alternatives do people have to improve their situation, and which alternatives do you recommend?

Fundamental Themes of Geography

In recent years, many geography teachers have learned that the five "fundamental themes" (Joint Committee on Geographic Education 1984) help them ask geographic questions. The theme of **Location** asks where things are and why things are located where they are. **Place** is the theme that inquires into human and physical characteristics of locations. **Human-Environment Interaction** examines how and why humans both adapt to and modify their environments as well as the consequences of these actions. **Movement** investigates not only how and why places are connected but also what is the significance of those interactions. The theme of **Region** seeks to identify and explain similarities and differences among areas and how and why these form and change. An extended explanation of the themes and their concepts, interrelationships, and applications is given in Hill and McCormick (1989). The themes are useful because they encourage the kinds of questions required to help students develop the geographic perspective.

Importance of Local Examples

GIGI is a world geography, but it shows that issues work at various geographic scales—personal, local, regional, national, and global. Because it is sometimes difficult for younger students to identify with faraway places, success with GIGI in part depends upon the ability of both you and your students to relate the issues to examples in your local community. We strongly recommend that you refer in class to local examples of the issue being investigated. Just as important, we encourage you to have your students conduct local field studies related to this issue whenever possible. Issues having important geographic dimensions abound in every community (see the Extension Activities and Resources section at the end of this Teacher's Guide for examples). Peak educational experiences often come when students see things in the field that relate to their classroom studies. We discuss other reasons for local involvement in the next section.

Familiar people can be as important as familiar places in motivating students. The quality of personal engagement is at the crux of successful instruction. Using the BGGS videodisc segments that accompany most GIGI lessons is a powerful way to help your students find relevance by identifying the GIGI issues with real people. Similarly, you can connect GIGI issues to everyday life at a human scale, especially at the students' own age levels, by using current newspaper accounts or magazines that address the student's perspective.

As you gain familiarity with teaching local examples, as you develop field exercises for your students, and as you learn how to put a human face on these materials, you will begin to customize the GIGI modules to fit your particular environment. Our trial teachers reported that the more they taught GIGI modules, the more comfortable they became in adapting them to fit their needs.

Fostering Optimistic and Constructive Perspectives

The seriousness and complexity of the global issues studied in GIGI can overwhelm students unless you take care to foster optimistic and constructive perspectives toward issues. "Gloom and doom" needs to be balanced with examples of success and prospects for positive change. It is important to help your students develop a sense of personal efficacy, an attitude that their actions can make a difference in solving global problems. The maxim, "Think Globally, Act Locally," speaks to the need to help students organize and conduct constructive actions that address local variants of the issues they are studying. As we noted earlier, student involvement in local projects enriches their educational experience. There is also good evidence that it actually produces an optimistic feeling—that their actions *can* make a difference—to help them deal with the often difficult and sometimes depressing world issues. GIGI modules often include lessons and activities to show possibilities for positive action.

Certain perspectives foster student optimism and constructive behavior. Geography students, especially, should learn to respect other peoples and lands, and they should come to cherish environmental unity and natural diversity. They should also learn to be skeptical about simplistic explanations, such as the theory that attempts to explain human characteristics and actions in terms of the physical environment alone, which geographers call "environmental determinism." Most important, optimistic and constructive perspectives accompany the development of empathy, tolerance, and open-mindedness. These traits are fostered by avoiding sexist and racist language, discouraging ethnocentricity, and challenging stereotypes, simplistic solutions, and basic assumptions.

References to Data

Unlike most textbooks, GIGI attributes its sources of data with in-text citations and full reference lists, which is another way of encouraging the critical perspective. In the Student DataBook, material that has been extracted from original sources is indented and printed in a different typeface. Long extracts are highlighted with background color. Use of these sources helps your students learn that real people construct ideas and data and that their concepts and information are not immutable. Instead, they often change through the critiques and interpretations of various people. By using these scholarly conventions, we intend to encourage your students to appreciate the tentativeness of knowledge and to value scholarship and academic integrity.

Updating

Real data quickly become obsolete. GIGI addresses this fact by discussing historical trends of data and by stressing concepts. You should reinforce this bias for concepts and also freely acknowledge the datedness of information by explaining why it is still used (for example, the lags between research and writing and publication and use; the lack of more recent data). Whenever possible, guide students to update materials. Britannica's Geopedia, on the BGGS CD-ROM, contains data based on Encyclopædia Britannica's World Data Annual, which is also available in print form. Have students use these sources to supplement and update GIGI data.

Assessing Learning

Evaluation of student achievements with GIGI can be focused on two broad areas. The first is the developing ability of students to undertake geographic inquiry. The second is the acquisition of knowledge and perspectives about the module issue.

The ability of students to undertake inquiry in geography can be related to the primary questions that guide geographical study. They are noted earlier in this memo. As students work through the module, they are likely to become increasingly adept at asking and answering geographic questions. Seek to extend your students' competence in several clusters of skills that facilitate geographic inquiry. These clusters include the following:

- Identifying problems and issues. This may be done through observation, asking questions, brainstorming, reading, and in other ways.
- Inquiring into the problems and issues in many ways such as through map reading and interpretation, making surveys, and using results of surveys done by others.
- Making decisions and taking action, for example, through reviewing alternatives, establishing priorities and criteria, and communicating cooperatively with people in other ways.
- Reflecting at all stages of the process of inquiry, especially through careful consideration of diverse sources of evidence.

Students will acquire knowledge of the module issue as they make their inquiries. This knowledge can be tested and graded. Assessments may be based on the following:

- Knowledge and skills shown by work on Activities included in this Teacher's Guide and on questions in the Student DataBook.
- Observations of student participation in groups and in class discussions.

Specific assessment ideas are given at the end of some lessons in the section called For Further Inquiry. In addition, the Teacher's Guide ends with Extension Activities and Resources. Some of these extension activities can serve as authentic assessments.

Potential Uses

In addition to the flexibility offered by the free-standing nature of the modules, GIGI has a number of other characteristics that encourage widespread use. Modules can be extended and enhanced with the BGGS CD-ROM, videodiscs, and posters. Because GIGI's issues-based approach integrates several topics (for example, population, economic, political, physical, and cultural geography) in a single module, the modules are not conducive to using an approach in which topics are taught separately. On the other hand, GIGI may be used with a world regional approach because there are modules for each of 10 world regions. A year-long world geography or global studies course will have more than enough material by using 12 modules. Five to seven modules may constitute a one-semester, issues-based geography course covering several regions. You can define clusters of modules for your own curricular purposes. We have identified three clusters for interdisciplinary studies within the Britannica Global Geography System, each comprising six or seven GIGI modules. They are *Earth's Environment and Society, Economic Development,* and *Global Political and Cultural Change.* BGGS includes a videodisc and poster for each cluster. These strand packages could well be used in Social and Environmental Studies, Earth Science, Global Studies, and Area Studies classes. Activities in the modules also support math, language arts, and arts curricula.

GIGI encourages and facilitates the development of a variety of geographic skills that transfer widely into the natural and social sciences. Among these are skills of asking geographic questions and developing and testing geographic generalizations. These require other GIGI skills including examining and making a variety of maps; analyzing photographs; constructing and interpreting graphs and tables of spatial data; and collecting, interpreting, and presenting geographic information.

Finally, GIGI promotes a wide variety of linguistic, numeric, oral, creative, and social skills as well as geographic skills. In particular, GIGI emphasizes cooperative learning. We believe that one of the great strengths of the GIGI modules is that they give students practice in both group and individual problem solving. As students become more familiar with the global issues, they learn that finding solutions to world problems requires people to work together cooperatively.

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Geography Education Standards Project. 1994. *Geography for Life: The National Geography Standards.* Washington, DC: Geography Education Standards Project.

Hill, A. David, and McCormick, Regina. 1989. *Geography: A Resource Book for Secondary Schools.* Santa Barbara, CA: ABC-Clio, Inc.

Joint Committee on Geographic Education. 1984. *Guidelines for Geographic Education: Elementary and Secondary Schools.* Washington, DC: Association of American Geographers and National Council for Geographic Education.

Slater, Frances. 1993. *Learning through Geography.* Revised. Indiana, PA: National Council for Geographic Education.

Preparing to Teach This Module

Sustainable Agriculture

How can the world achieve sustainable agriculture?

This module acquaints students with the issue of sustainable agriculture through study of agricultural problems in Malaysia, Africa, and the United States. Studying sustainable agriculture requires looking at many aspects of farming practice. The module examines both the physical constraints on agriculture as well as the economic and political considerations that dictate agricultural policies. At the end of the module, students develop strategies to address environmental problems related to modern agriculture.

The module provides many opportunities to examine the five themes of geography. Most important to this module is the theme of *Human-Environment Interaction.* Agriculture is one of humanity's most fundamental environmental modifications. The real issue of this module is how we can ensure that this modification does not ruin the environment, so that future generations will be able to feed themselves. In addition, the theme of *Place* is central. A major point of the module is that agricultural methods must consider the local physical and cultural characteristics of a place to be workable. Activities also look at the themes of *Location and Region.*

The module begins by defining *sustainable agriculture.* A summary of those modern farming practices that are unsustainable forms the core of Lesson 2. The Student DataBook describes how conventional farming methods deplete water, soil, and energy resources. As the module progresses, students will not only see the need for sustainable agriculture but also see a conflicting need to increase agricultural output to meet the needs of a growing population. Yet there are physical constraints on agriculture in the developing world, as Lesson 3 makes clear. This lesson addresses some basic relationships in physical geography, so students can examine the agricultural problems of tropical soils.

Lessons 4 and 5 comprise the case study of Malaysia. The fourth lesson introduces students to the physical and cultural characteristics of Malaysia. Lesson 5 is the central case study of Malaysian agricultural practices. Students, working in groups, work with text descriptions of how Malaysia's main crops are grown and decide whether the practices are sustainable in terms of water, soil, and energy resources.

Lessons 6 and 7 compare the issue in other regions. Lesson 6 looks at sustainable farming methods in tropical Africa. This lesson should leave students feeling somewhat optimistic, but a key point is made that introducing such systems is costly and requires institutional support. In the study of U. S. agriculture (Lesson 7), two problems are examined: erosion and overproduction. Students also compare a conventional farm with a sustainable one. Again, the discussion leaves room for more questions about the role of government support for unsustainable agricultural practices. Lesson 8 concludes the module by returning to the global scale. Students, drawing on material from throughout the unit, decide which strategies would help ensure adoption of sustainable agriculture worldwide. It should be recalled that research on sustainability is still being conducted and that some answers have not yet been discovered.

It is assumed that students will have some understanding of global population growth and of the environmental problems caused by agriculture (even if it's just the idea that chemical fertilizers, herbicides, and pesticides pollute ground and water).

Using the BGGS CD-ROM can simplify lesson planning by making it easy to access the resources the system provides for each lesson. It shows exactly which Geopedia™ data and learning activities can be used in long-range and short-term assignments, and which videodisc clips will provide visual reinforcement for each GIGI lesson. The CD-ROM can also show you ways in which a lesson in one module relates to a lesson in another module. And it indicates where to find every reference in GIGI, Geopedia™, the Mini-Atlas maps, and the videodiscs to any key topic—for example, "tsunami" or "Bangladesh." The students will also be able to use the BGGS CD-ROM for further research and short-term or long-term range assignments. The BGGS multimedia components and their uses are explained fully in the tabbed BGGS section in the front of this Teacher's Guide.

The following are general modifications recommended for younger students:

- Plan for fifteen days because the activities will require more teacher explanation and support.
- Provide directions for homework assignments and monitor students' understanding and progress.
- Prior to assigning written activities requiring students to draw conclusions and summarize their findings, ask guiding questions and develop a sample outline on the chalkboard.

Module Objectives

- Define *sustainable agriculture* and give examples of how it differs from conventional agricultural practices.
- Recognize the importance of sustainable agriculture for the future of human life.
- Explain why tropical soils are less fertile than soils in the mid-latitudes.
- Describe the kinds of farming practices that maintain soil fertility in tropical areas.
- Recognize that decisions concerning agriculture are guided by political, economic, and cultural considerations.

Number of Days Required to Teach *Sustainable Agriculture*

About thirteen 50-minute class periods. Teachers in grades 7–8 should allow about fifteen periods.

Suggestions for Teacher Reading

Eisenberg, Evan. 1989. Back to Eden. *Atlantic Monthly,* November: 57–89. This is an excellent and readable summary of the problems of conventional agriculture and the goals of sustainable agriculture. The discussion features interviews with Wes Jackson and descriptions of sustainable agriculture programs at the Land Institute in Kansas.

Reganold, John P., Papendick, Robert I., and Parr, James F. 1990. Sustainable agriculture. *Scientific American,* June: 112–120. This is a somewhat more detailed treatment of the ecological rationale underlying sustainable agriculture.

Mellor, John W. 1988. The intertwining of environmental problems and poverty. *Environment,* November.

Oram, Peter A. 1988. Moving toward sustainability: building the agroecological framework. *Environment,* November: 14–17, 30–36.

Orians, Gordon H. 1990. Ecological concepts of sustainability. *Environment,* November. This is a useful piece on sustainable agriculture.

York, E. T., Jr. 1988. Improving sustainability with agricultural research. *Environment,* November.

Lesson 1

What is sustainable agriculture and why is it important?

Time Required

Two 50-minute class periods

Materials Needed

Copies of Activity 1 for each pair of students

Glossary Words

arable land

domestication

ecosystem

fodder

marginal land

monocropping

pesticide

soil

Getting Started

- Have students read the Memo to the Student and the overview on pages 2–3 in the Student DataBook prior to beginning the module. Also make sure students are aware that there is a Glossary in the back of their DataBooks.
- Ask students how many of their families were living on a farm when they (the students) were born. How about when their parents were born? Grandparents? In most cases (except perhaps in rural communities), the trend will be toward fewer U.S. families living on farms. (Classes in rural areas may speculate what the patterns in other settings would be.) Ask how many students have ever been on a farm. Tell the class that in 1860 over half of all people in the United States lived on farms and rural communities. Today less than 2 percent of the U.S. population actually farms.
- Next ask: If the number of people farming in the United States has declined, how can enough food still be produced to feed growing populations? Students may be aware that agricultural productivity has been increased by technology. If not, the first activity in this lesson should clarify this important point. Three technologies are important: the use of fertilizers synthesized from petroleum-based chemicals; the expansion of agriculture into semiarid areas as a result of irrigation; and the development of higher-yielding breeds of crops by plant geneticists. Some students may have heard of "The Green Revolution," which describes these technological breakthroughs used to increase food production.
- To get students thinking about the agricultural problems facing the world, it helps to make them aware first of local soil and farming problems. Ask an agent from the local extension office of the Soil Conservation Service (SCS) to make a presentation to your class. The agent can describe the types of soil in your region, the fertility of these soils, and the constraints or limitations on their utility, both for agriculture and other uses. If you are in a rural area, arrange a visit to a nearby farm where students can ask questions. If you are in an urban or suburban area, arrange for a visit to an urban farm garden project (found in many cities) or ask a representative from a garden cooperative or local organic gardening organi-

zation to visit and discuss the methods for dealing with local soil problems.

Alternatively, obtain copies of the SCS Soil Survey for your county. Numerous opportunities for map activities can be developed from these books, which are good resources for discussing land-use planning in your local area. For example, students can identify the soil type mapped for their neighborhood and compare the actual land uses to the suggestions given in the Soil Survey. These books can be used in suburban and urban areas as well as in rural counties.

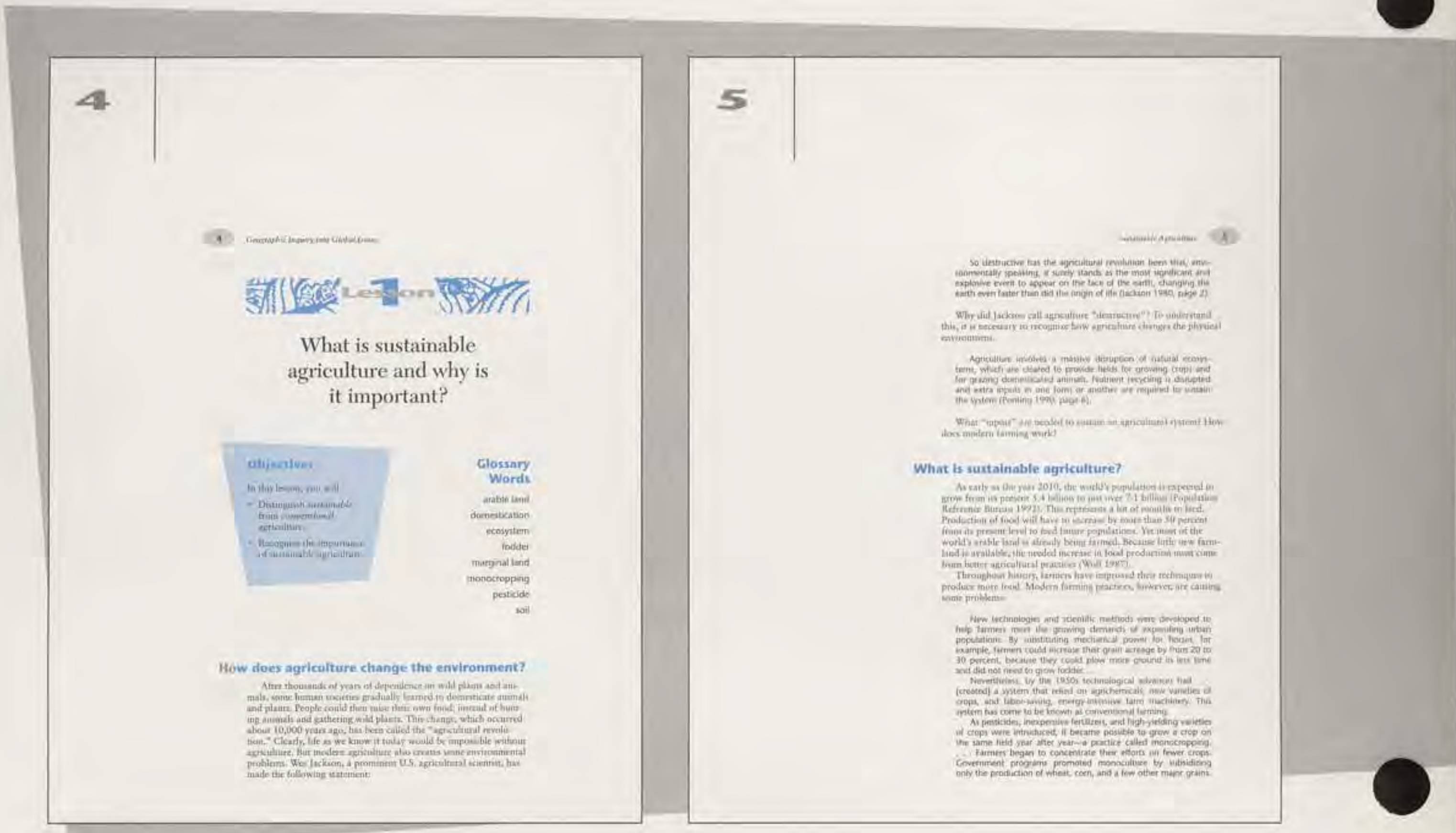
Procedures

How does agriculture change the environment? (pages 4–5)

A. Have a couple of students read the text on pages 4–5. The section concludes with two questions for discussion. To answer these questions about how modern farming actually works, hand out copies of **Activity 1** to students, who can work in pairs on this. Explain that the Activity lists some terms related to agriculture. Ask students to arrange the terms into two lists. One list should be of what the farmer does or uses to work the land to grow crops (inputs). The other should be of results of the work (outputs). Some results may not be intended by the farmer; have students put a star beside those that might be harmful to the environment (see *Key for Activity 1*).

Work with students to identify the six negative effects (those that have been given a star), and discuss these effects with them. This will indicate to what extent students are aware of environmental problems before studying the module. Have students classify the six negative effects into the following three groups (see *Key for Activity 1*):

- Effects involving water
- Effects involving soil
- Effects involving fossil fuels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Lesson 1

What is sustainable agriculture and why is it important?

Objectives

Glossary Words

arable land

domestication

ecosystem

fodder

marginal land

monocropping

pesticide

soil

How does agriculture change the environment?

After thousands of years of dependence on wild plants and animals, some human societies gradually learned to domesticate animals and plants. People could then raise their own food, instead of hunting animals and gathering wild plants. This change, which occurred about 10,000 years ago, has been called the "agricultural revolution." Clearly, life as we know it today would be impossible without agriculture. But modern agriculture also creates some environmental problems. Wes Jackson, a prominent U.S. agricultural scientist, has made the following statement:

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So destructive has the agricultural revolution been that, environmentally speaking, it surely stands as the most significant and explosive event to appear on the face of the earth, changing the earth even faster than did the origin of life (Jackson 1980, page 2).

Why did Jackson call agriculture "destructive"? To understand this, it is necessary to recognize how agriculture changes the physical environment.

What is sustainable agriculture?

New technologies and scientific methods were developed to help farmers meet the growing demands of expanding urban populations. By substituting mechanical power for horses, for example, farmers could increase their grain acreage by from 20 to 30 percent, because they could plow more ground in less time and did not need to grow fodder. . . .

As pesticides, inexpensive fertilizers, and high-yielding varieties of crops were introduced, it became possible to grow a crop on the same field year after year—a practice called monocropping. . . . Farmers began to concentrate their efforts on fewer crops. Government programs promoted monoculture by subsidizing only the production of wheat, corn, and a few other major grains.

This three-part division is used throughout the module to classify environmental problems associated with conventional agriculture. Challenge students to identify which specific inputs might lead to the harmful results. Not all answers may be apparent, but later work in the module addresses this issue.

> Younger students may not understand all the terms in Activity 1. Perhaps a display could be arranged ahead of time with magazine pictures of each term. If students are unfamiliar with the term *fossil fuels* (referring to oil, coal, and natural gas), be sure they know that these resources are derived from fossilized remains of plants and animals that are millions of years old. Also, you can guide younger students through the reading instead of having them read it themselves.

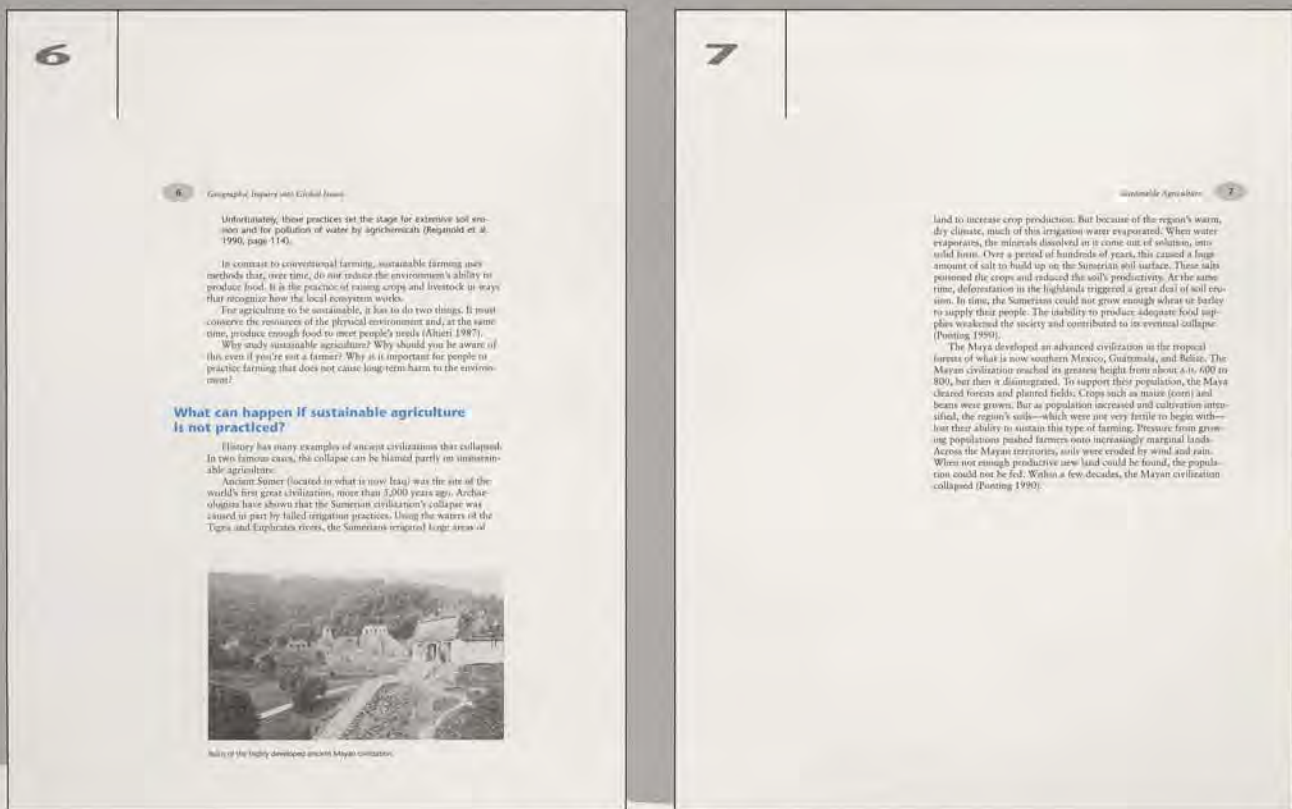
What is sustainable agriculture? (pages 5–6)

B. Have students read this section. Focus discussion around the difference between conventional and sustainable agriculture.

Ask if anyone has spent any time on a farm. Encourage students to describe their own experiences and to describe what kinds of methods are used in farming. [Perhaps students will recall farm machinery or other items listed in the reading.] Ask if anyone has noticed organic or "natural" foods in the market and whether the availability of such products has increased over the last few years. If so, why? [Perhaps because of increasing concern about the environment]

Be sure students understand that agrichemical fertilizers are derived from petroleum. The reading also indicates that monocropping can lead to extensive soil erosion. This is because when entire fields of one crop are harvested, all of the soil is laid bare. If multiple crops are grown, then some of the soil is covered at all times. Be sure students also note the role that government policies play; later lessons return to this topic.

The final question in the section leads to the next section. The purpose is for students to recognize that unsustainable agriculture has, in extreme cases, led to the collapse of entire civilizations.



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6 *Geographic Inquiry into Global Issues*

> Unfortunately, these practices set the stage for extensive soil erosion and for pollution of water by agrichemicals (Reganold et al. 1990, page 114).

In contrast to conventional farming, sustainable farming uses methods that, over time, do not reduce the environment's ability to produce food. It is the practice of raising crops and livestock in ways that recognize how the local ecosystem works.

For agriculture to be sustainable, it has to do two things. It must conserve the resources of the physical environment and, at the same time, produce enough food to meet people's needs (Altieri 1987).

Why study sustainable agriculture? Why should you be aware of this even if you're not a farmer? Why is it important for people to practice farming that does not cause long-term harm to the environment?

What can happen if sustainable agriculture is not practiced?

History has many examples of ancient civilizations that collapsed. In two famous cases, the collapse can be blamed partly on unsustainable agriculture.

Ancient Sumer (located in what is now Iraq) was the site of the world's first great civilization, more than 5,000 years ago. Archaeologists have shown that the Sumerian civilization's collapse was caused in part by failed irrigation practices. Using the waters of the Tigris and Euphrates rivers, the Sumerians irrigated large areas of

Ruins of the highly developed ancient Mayan civilization.

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Sustainable Agriculture 7

land to increase crop production. But because of the region's warm, dry climate, much of this irrigation water evaporated. When water evaporates, the minerals dissolved in it come out of solution, into solid form. Over a period of hundreds of years, this caused a large amount of salt to build up on the Sumerian soil surface. These salts poisoned the crops and reduced the soil's productivity. At the same time, deforestation in the highlands triggered a great deal of soil erosion. In time, the Sumerians could not grow enough wheat or barley to supply their people. The inability to produce adequate food supplies weakened the society and contributed to its eventual collapse (Ponting 1990).

The Maya developed an advanced civilization in the tropical forests of what is now southern Mexico, Guatemala, and Belize. The Mayan civilization reached its greatest height from about A.D. 600 to 800, but then it disintegrated. To support their population, the Maya cleared forests and planted fields. Crops such as maize (corn) and beans were grown. But as population increased and cultivation intensified, the region's soils—which were not very fertile to begin with—lost their ability to sustain this type of farming. Pressure from growing populations pushed farmers onto increasingly marginal lands. Across the Mayan territories, soils were eroded by wind and rain. When not enough productive new land could be found, the population could not be fed. Within a few decades, the Mayan civilization collapsed (Ponting 1990).

What can happen if sustainable agriculture is not practiced? (pages 6–7)

C. Have students read (aloud, if you wish) the two descriptions of failed civilizations. Have students locate the sites of these ancient civilizations. Ask students which of the Sumerian and Mayan practices are still in use today. [Irrigation in dry climates; planting on marginal lands; expanding agriculture to feed growing populations]

These two readings are frankly designed to alarm students somewhat to attract interest in the module. If time permits, have older students critique why these particular readings were included in the module. This is a good exercise in evaluating texts for their purposes. Have students consider what information might be presented in a module trying to promote conventional agriculture. Challenge older students to locate such materials at the library.

For Further Inquiry

- Assign a short essay, due the next day, in which students explain what sustainable agriculture is, why it is important, and how it differs from conventional agriculture.
- Have students create drawings to show how certain conventional agricultural inputs can lead to environmental problems. Drawing the concept requires use of creativity and different modes of expression.

Lesson 2

What environmental problems does conventional farming cause?

Time Required

One 50-minute class period

Materials Needed

Copies of Activity 2 for all students

Glossary Words

aquifer

hectare

nonrenewable resource

pesticide

renewable resource

soil

topsoil

Getting Started

Lead students in a discussion of the examples (end of Lesson 1) of the Sumerian and Mayan civilizations, which failed as a result of poor agricultural practices. These readings may spark some interest in the issue of sustainable agriculture.

Procedures

Why is conventional farming *not* sustainable? (pages 8–14)

A. Ask the class to define *renewable* and *nonrenewable* resources. If they are unclear about the difference, the text provides short definitions on page 8. Discuss Questions 1–2 on page 9.

8

8 Geographic Inquiry into Global Issues

Lesson 2

What environmental problems does conventional farming cause?

Objectives

In this lesson, you will:

- Give examples of renewable and nonrenewable resources.
- Explain three environmental problems caused by conventional farming.

Glossary Words

aquifer
hectare
nonrenewable resource
pesticide
renewable resource
soil
topsoil

Why is conventional farming *not* sustainable?

To put this question in context, we must define two terms: renewable resources and nonrenewable resources.

A renewable resource is one that cannot be used up because it is regularly replenished. This means that it can be renewed by natural processes. The important point is that the rate of resource use is slower than the rate of renewal.

Nonrenewable resources, on the other hand, are those that cannot be replaced by natural processes because the rate of resource use is faster than the natural rate of renewal (Miller 1986).

Questions and Answers for page 9

1. What are some examples of renewable resources? Of nonrenewable resources?
   - These lists are not comprehensive: Examples of renewable resources are solar energy; wind power; carefully managed forests, fisheries, livestock, and soils (i.e., used slower than rate of replacement). Nonrenewable resources are fossil fuels; metals; and poorly managed forests, fisheries, livestock, and soils (i.e., used faster than rate of replacement).

2. Would sustainable agriculture use resources faster or slower than they could be renewed? Explain your answer.
   - Sustainable agriculture manages resources so that they are renewable.

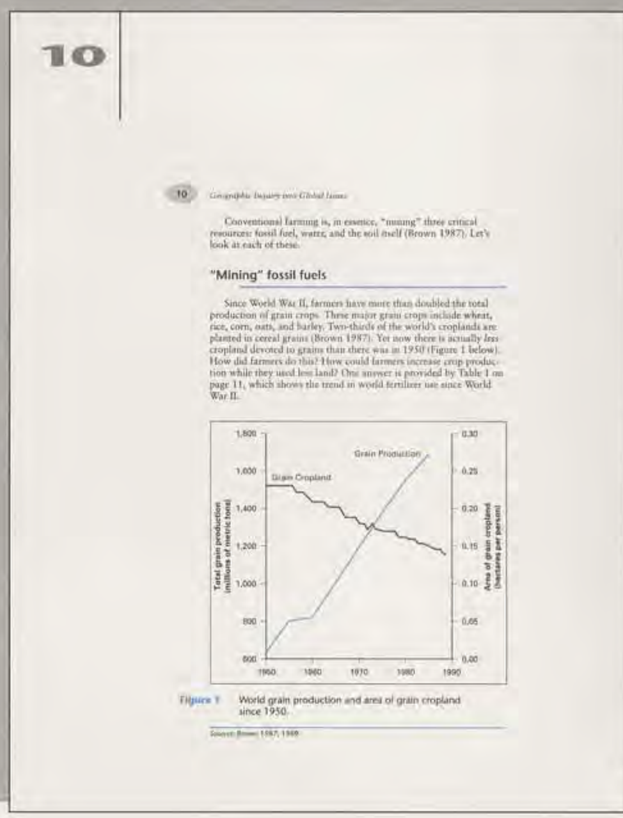
B. Have students read the quote from Eisenberg on page 9. Have the class list all the environmental problems cited in this quote and ask whether conventional agriculture treats resources as renewable or nonrenewable. [The reading makes clear the point that conventional agricultural practices use resources at a rate that renders them nonrenewable.]

At this point the module introduces the device of discussing agriculture in terms of its use of fossil fuel, water, and soil resources. You may wish to discuss the idea of "mining" resources in contrast to "recycling" them. Ask students why recycling is important. [Recycling metals, glass, and newspaper, among other items, prolongs the availability of nonrenewable resources.]

The following excerpt from a magazine article summarizes some of the problems with conventional farming, as it has been practiced in the United States during the twentieth century. As you read, consider these questions: *Are these conventional agricultural practices treating resources as renewable or nonrenewable? How do you know?*

> A third of [U.S.] farmland topsoil, accumulated over millennia, [has been lost in the last century]. For every bushel of corn that Iowa grows, it sheds at least two bushels of soil. Farm runoff is poisoning our drinking water. . . . In 1948, at the dawn of the chemical age, American farmers used 15 million pounds of insecticides and lost 7 percent of their crops to insects; today they use 125 million pounds and lose 13 percent. Because most agricultural chemicals are made from fossil fuels, we [use] three calories of energy to produce each calorie of food we eat. . . . In contrast, Tsembaga farmers in highland New Guinea, using Neolithic slash-and-burn methods, [use] less than a tenth of a calorie for each calorie they eat. For each American man, woman, and child, our agriculture [uses] 160 pounds of nitrogen, phosphate, and potash fertilizer each year, and 325 gallons of water each day. The Ogallala aquifer of the Great Plains held enough water forty years ago to fill Lake Huron; in another twenty years it may be too low to pump. The great dams of the West are silting up. Sloppy irrigation and poor drainage . . . have caused [salty] conditions on 10 percent of our crop and pasture land. Should we escape the fate of the ancient empires that were done in by erosion, we may instead face that of the Sumerians, whose civilization crumbled as their soil turned salty (Eisenberg 1989, page 59).

A useful way to think of nonrenewable resources is to think about mining. Gold, silver, tin, and all metals mined from Earth are nonrenewable resources. Metal ores were formed by geological processes that happened over millions of years. Such processes cannot renew these ores for many more millions of years. So, every metal mined from Earth is, for society's purposes, irreplaceable.



Questions and Answers for page 11

3. Why do you think grain production is used as an indicator for *total* food production? Do you think this is a good way to estimate food totals? Why or why not?
   - Grain production is used as a surrogate for total food production because cereal grains (wheat, corn, oats, rice, etc.) are the main staples of human diet around the world. Whether students think this is valid is up to them; if not, they should be prepared to offer alternatives.

4. What has been the relationship between world fertilizer use and world grain production? Why would this relationship exist?
   - Students are likely to see a direct relationship, that is, as fertilizer use has increased, production has increased. This is because adding fertilizer to soil increases the size and growth rate of crop plants.

5. Why have farmers increased their use of fertilizer?
   - Students can speculate that the desire to grow more crops has caused farmers to increase fertilizer use. This would, besides providing more food for growing populations, provide greater income to the farmer (as long as there is a market for the crop). More astute students may also recall that government policies can sometimes encourage farmers to produce more. To increase production, some governments have paid the costs or *subsidized* fertilizer use.

C. **"Mining" fossil fuels:** Figure 1 on page 10 presents a paradox: greater food production on less acreage. Have students speculate how this was done. [Improvements in agricultural technologies are the key here, as noted in Lesson 1. Farmers can increase production by using higher-yielding varieties of crops, adding fertilizer to soil, irrigating, and so on.] Now have students examine Table 1 on page 11, and working in small groups, answer Questions 3–5.

D. Table 2 on page 12 presents data showing how the use of fossil fuel has increased to support the growth in food production. This is an essential point: Modern agricultural production has been founded on increased use of petroleum—a nonrenewable resource. Table 2 breaks this consumption down into fuel used for machinery, oil used to manufacture fertilizers, and others.

   Distribute copies of **Activity 2** to each student. First, have students add the three columns in Table 2 to obtain the total energy use. Next, they can graph the total column for

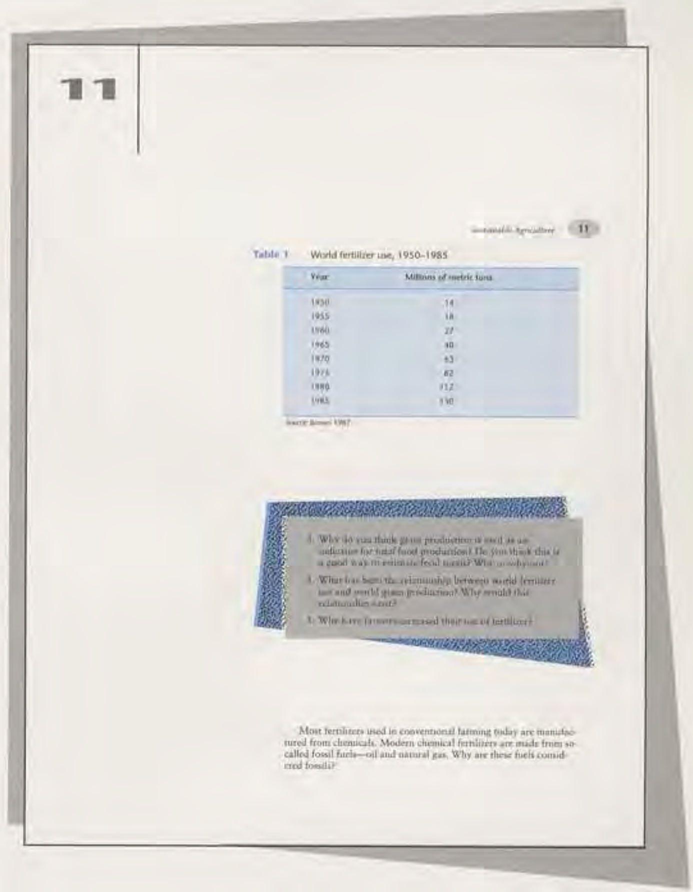

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Table 1 World fertilizer use, 1950–1985

Year	Millions of metric tons
1950	14
1955	18
1960	27
1965	40
1970	63
1975	82
1980	112
1985	130

each of the five years (see *Key for Activity 2*). Have students, perhaps working in pairs, analyze the trends shown on their completed Activities and answer Questions 6–9 on page 12.

Older students can do more complex graphs: for example, they can plot the data for each of the three columns rather than the total and analyze the trends for each type of use. (They may note a slight increase in fertilizer use relative to fuel use.)

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12 *Geographic Inquiry into Global Issues*

Table 2 Energy use in world agriculture (millions of barrels of oil)

Year	Fuel*	Fertilizer manufacture	Other**
1950	160	70	46
1960	321	133	81
1970	498	310	162
1980	789	552	268
1985	940	846	317

Notes: *Fuel = fuel for tractors and other farm machines, including irrigation equipment. **Other = energy used to (1) synthesize pesticides, (2) manufacture farm machinery, (3) apply fertilizers, and (4) dry grain. Figures are estimates because no reliable data exist.

Source: Brown 1987.

6. About how many years did it take for the 1950 level of total agricultural energy use to double?
7. About how many more years did it take to double again? What would you predict total energy use to be in the year 2000?
8. What resource do fertilizers, pesticides, and farm machinery all depend on? Is this a renewable resource?
9. Do you think the increasing use of fertilizer is a sustainable practice? Why or why not?

"Mining" water

In what two ways can farmers obtain water for their crops? Would you consider water used by farmers to be a renewable or nonrenewable resource? Why? Under what circumstances would agricultural water supplies be nonrenewable?

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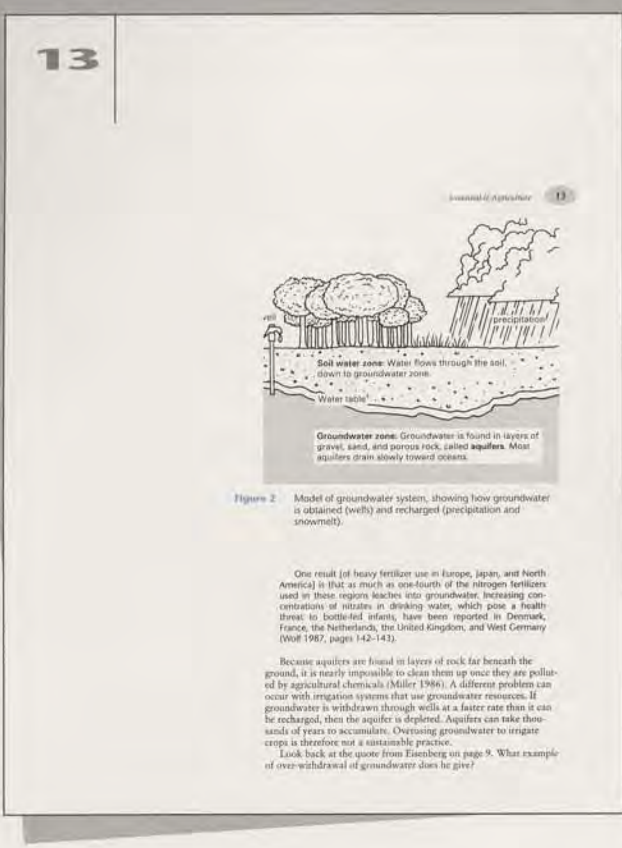
Sustainable Agriculture 13

Figure 2 Model of groundwater system, showing how groundwater is obtained (wells) and recharged (precipitation and snowmelt).

One result [of heavy fertilizer use in Europe, Japan, and North America] is that as much as one-fourth of the nitrogen fertilizers used in these regions leaches into groundwater. Increasing concentrations of nitrates in drinking water, which pose a health threat to bottle-fed infants, have been reported in Denmark, France, the Netherlands, the United Kingdom, and West Germany (Wolf 1987, pages 142–143).

Because aquifers are found in layers of rock far beneath the ground, it is nearly impossible to clean them up once they are polluted by agricultural chemicals (Miller 1986). A different problem can occur with irrigation systems that use groundwater resources. If groundwater is withdrawn through wells at a faster rate than it can be recharged, then the aquifer is depleted. Aquifers can take thousands of years to accumulate. Overusing groundwater to irrigate crops is therefore not a sustainable practice.

Look back at the quote from Eisenberg on page 9. What example of over-withdrawal of groundwater does he give?

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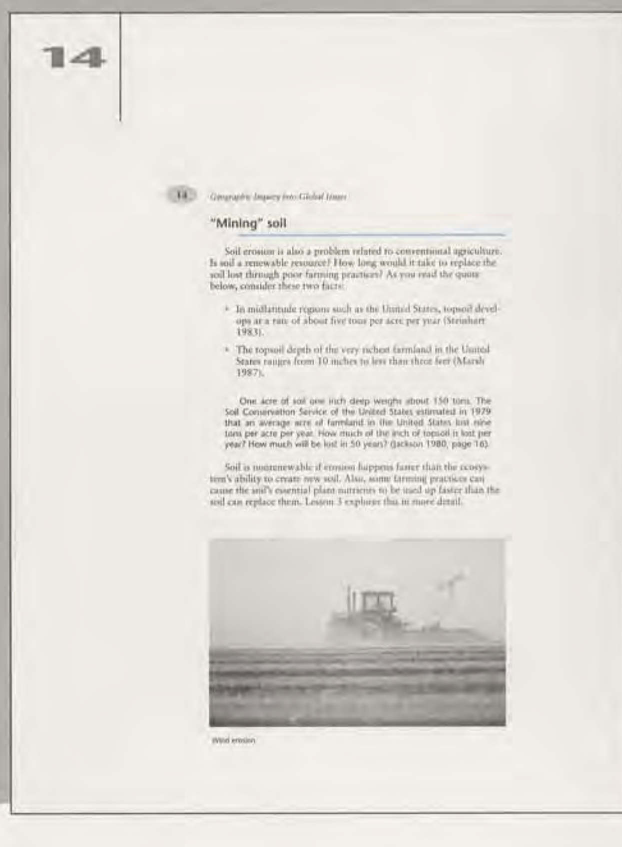

14 *Geographic Inquiry into Global Issues*

"Mining" soil

Soil erosion is also a problem related to conventional agriculture. Is soil a renewable resource? How long would it take to replace the soil lost through poor farming practices? As you read the quote below, consider these two facts:

- In midlatitude regions such as the United States, topsoil develops at a rate of about five tons per acre per year (Steinhart 1983).
- The topsoil depth of the very richest farmland in the United States ranges from 10 inches to less than three feet (Marsh 1987).

One acre of soil one inch deep weighs about 150 tons. The Soil Conservation Service of the United States estimated in 1979 that an average acre of farmland in the United States lost nine tons per acre per year. How much of the inch of topsoil is lost per year? How much will be lost in 50 years? (Jackson 1980, page 16)

Soil is nonrenewable if erosion happens faster than the ecosystem's ability to create new soil. Also, some farming practices can cause the soil's essential plant nutrients to be used up faster than the soil can replace them. Lesson 3 explores this in more detail.

Wind erosion

Questions and Answers for page 12

6. About how many years did it take for the 1950 level of total agricultural energy use to double?
   - Energy use approximately doubled between 1950 and 1960.

7. About how many more years did it take to double again? What would you predict total energy use to be in the year 2000?
   - It doubled again, or nearly so, in 10 more years. Predictions for the year 2000 will vary. Students should see that the 1970 level approximately doubled again by 1985, so it would be reasonable to expect another doubling by 2000. The purpose of this exercise is not for precise estimates, but for students to see how rough trends can be described from tables and graphs. Some students might try to extend their graphed line to figure out when the total energy use will double; this is the right idea and should be encouraged.

8. What resource do fertilizers, pesticides, and farm machinery all depend on? Is this a renewable resource?
   - All these uses depend upon a nonrenewable resource, petroleum.

9. Do you think the increasing use of fertilizer is a sustainable practice? Why or why not?
   - This increasing reliance on nonrenewable resources is not sustainable. The key point is that agriculture has become more reliant on fossil fuels to increase crop productivity. But the availability of petroleum is declining, especially for poor countries who may not be able to afford its rising cost. A point for debate, however, is just how long the oil resource will last.

E. **"Mining" water:** This section (pages 12–13) opens with several brief questions, which can be skipped if time is short. [Farmers can get water either from precipitation (rain, snow) or from irrigation. Irrigation comes from either surface water or groundwater resources. Water would be nonrenewable if it is used faster than it can be replenished by natural processes.] Figure 2 is included so students can see graphically how groundwater is recharged by precipitation. The familiar water well draws directly from this resource. The text makes clear that groundwater is nonrenewable under the circumstances described. Eisenberg cited the example of the overdrawing of the Ogallala Aquifer.

F. **"Mining" soil:** As in the case of water, this is a case where a resource can be either renewable or nonrenewable, depending upon how it is managed. The quote from Jackson on page 14 makes the point that, under conventional agriculture, erosion is proceeding so fast that soil is becoming nonrenewable. Have students do some quick calculations to verify this. [If topsoil develops at 5 tons/acre per year but is being lost at 9 tons/acre per year, then nearly twice as much soil is being eroded than is being formed. By definition, this means the usage is unsustainable.]

Older students can take this analysis a step further, using a little more algebra. If an inch of soil weighs 150 tons, and nearly 10 tons are lost per year, then it will take only 15 years to erode the inch completely. If the very best topsoils are 10 inches deep, then no usable soil will be available in perhaps 150–200 years. This may seem a long time, but soils take thousands of years to develop to such depths. Again, the numbers suggest that present erosion rates are unsustainable.

Lesson 3

Why do soils differ from place to place?

Time Required

Two or three 50-minute class periods

Materials Needed

Two or three samples of local soils displaying different characteristics
Mini-Atlas maps 1, 2, and 3

Glossary Words

humus

leaching

legumes

nitrogen fixation

plant nutrients

soil

soil fertility

Getting Started

- Bring in two or three samples of local soil, making sure that each sample is distinctive and different in some way from the others. Divide students into small groups of three or four, and ask them how soils differ from place to place. They may need some prodding to get beyond dismissing soil as mere dirt. Encourage groups to notice, for example, differences in soil color. Are some soils darker than others? Are some redder? Another noticeable feature of soils is texture, meaning how much sand or clay is in the soil. Ask students if some soils feel different from others. How can one tell? [Sands feel gritty; clays feel sticky and muddy.] Challenge your students to use all their senses (except taste!) to observe and describe the soils. Have each group read aloud their list of observations. You can make a game out of describing each soil sample, having groups compete to discover the most relevant observations.
- Even better, spend a class period outside on the school grounds having students look closely at soil. It is worth this extra time to let students get their hands on some soil. Playing with and talking about soil will be a nice diversion from the reading and data analysis of the module. If you can arrange time in the field, have students record their observations about soil differences and submit a field report, including sketches. The significance of variables such as color and texture is described in any introductory text in physical geography. Middle school students might do this sort of exercise teamed with their earth science class.

Procedures

A. The lesson opens with a short excerpt, "The critical importance of healthy, fertile soil" on pages 15 and 16. Discuss this quote and Questions 1–2 briefly.

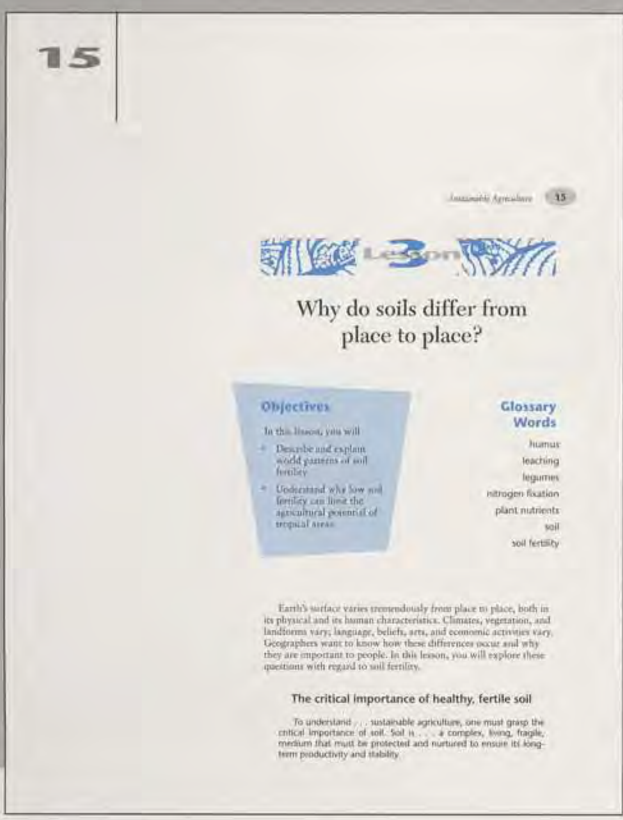
Questions and Answers on page 16

1. How does healthy soil promote plant growth?
    - Healthy soil allows free circulation of air and water and is home to countless organisms that decompose organic matter, enriching the soil with essential nutrients.
2. What is meant by *nitrogen fixation* and why is it important?
    - Nitrogen fixation is a process that converts atmospheric nitrogen gas into nutrient compounds (e.g., nitrates) that plants can use.

Where is soil fertility high? Where is it low? (pages 17–18)

B. Prior to beginning the analysis of Figure 3 on page 18, be sure students understand the meanings of the terms *tropical* and *midlatitude*. Select students to come forward and have them locate the two tropics (Cancer and Capricorn) and the Arctic and Antarctic circles, using a wall map of the world.

Ask students how one could define *tropical*, *midlatitude*, and *polar* using these four reference lines. [A reasonable answer, although not all would agree on this, is that the area between the two tropics is tropical; the areas between each tropic and the appropriate circle is midlatitude—23.5° to 66.5°N and S; and the areas poleward of each circle are polar.]


15

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Lesson 3

Why do soils differ from place to place?

Objectives

In this lesson, you will

- Describe and explain world patterns of soil fertility
- Understand why low soil fertility can limit the agricultural potential of tropical areas

Glossary Words

humus
leaching
legumes
nitrogen fixation
plant nutrients
soil
soil fertility

Earth's surface varies tremendously from place to place, both in its physical and its human characteristics. Climates, vegetation, and landforms vary; language, beliefs, arts, and economic activities vary. Geographers want to know how these differences occur and why they are important to people. In this lesson, you will explore these questions with regard to soil fertility.

The critical importance of healthy, fertile soil

To understand . . . sustainable agriculture, one must grasp the critical importance of soil. Soil is . . . a complex, living, fragile, medium that must be protected and nurtured to ensure its long-term productivity and stability.


16

16 Geographic Inquiry into Global Issues

Soybean root nodules contain nitrogen-fixing bacteria

Healthy soil is a hospitable world for growth. Air circulates through it freely, and it retains moisture long after a rain. A tablespoon of soil contains millions of grains of sand, silt, and clay . . . to which plant nutrients may cling. That same tablespoon of soil also contains billions of microorganisms, including bacteria, fungi, and algae, most of which are principal decomposers of organic matter. Decomposition results in the formation of humus and the release of many plant nutrients. The microbes also produce sticky substances that glue soil particles together and help the soil to resist erosion.

Another essential activity that takes place in the soil is the fixation of nitrogen. Certain bacteria in the soil or in the roots of plants (most notably legumes [such as peas, alfalfa, and soybeans]) convert atmospheric nitrogen gas into fixed forms of nitrogen that plants . . . use to make proteins. The amount of available nitrogen strongly influences soil productivity (Reganold et al. 1990, page 112).

1. How does healthy soil promote plant growth?
2. What is meant by *nitrogen fixation* and why is it important?

Ask students in which zones the United States falls. [This is a tricky question: The lower 48 are in the midlatitudes, but Hawaii is tropical and parts of Alaska are polar.]

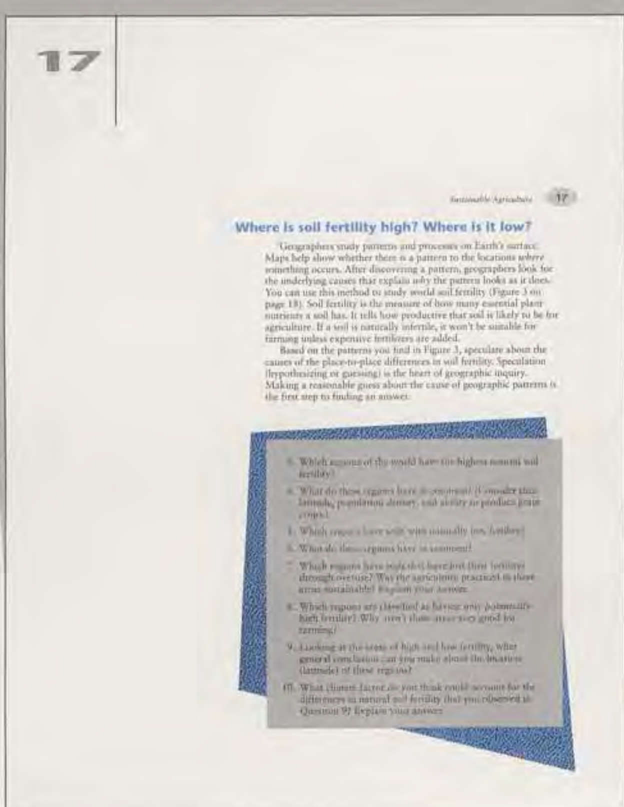
Ask students how climate characteristics differ between the tropics and midlatitudes. [The key point is that the tropics are warmer year round. Midlatitude areas have more pronounced seasonal differences: cooler in winter, warmer in summer.]

> Younger students may need more guidance here; for high school students this should be a review. Use **Mini-Atlas map 1** of world climates as a resource. It may also be useful to ask any students who have traveled to describe their experiences in different climates. Also, students may have images of tropical climates from movies or TV.

C. Have students now begin their analysis of the world map of soil fertility (Figure 3). Emphasize that this models geographic research: Examine spatial patterns, reach general conclusions, and seek explanations for these patterns. The first part of the exercise is the search for patterns of world soil fertility. Have students work in pairs or groups of three or four to answer Questions 3–10.

Have a wall map of the world visible so students can identify places easily. Also hand out **Mini-Atlas maps 2** and **3.** Groups should seek commonalities in the soil fertility pattern based on:

- Location (general latitude, using Figure 3);
- Population distribution; and
- Production of grain crops (wheat, rice, corn, etc.).



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Where is soil fertility high? Where is it low?

Geographers study patterns and processes on Earth's surface. Maps help show whether there is a pattern to the locations *where* something occurs. After discovering a pattern, geographers look for the underlying causes that explain *why* the pattern looks as it does. You can use this method to study world soil fertility (Figure 3 on page 18). Soil fertility is the measure of how many essential plant nutrients a soil has. It tells how productive that soil is likely to be for agriculture. If a soil is naturally infertile, it won't be suitable for farming unless expensive fertilizers are added.

Based on the patterns you find in Figure 3, speculate about the causes of the place-to-place differences in soil fertility. Speculation (hypothesizing or guessing) is the heart of geographic inquiry. Making a reasonable guess about the cause of geographic patterns is the first step to finding an answer.

Questions and Answers for page 17

3. Which regions of the world have the highest natural soil fertility?
   - The regions with the highest natural soil fertility are east-central North America; northern Europe; eastern China; Japan; eastern midlatitudes of South America; northern India; Nile River valley; and parts of Southeast Asia.

4. What do these regions have in common? (Consider their latitude, population density, and ability to produce grain crops.)
   - Most places are in the midlatitudes, and they are important grain production areas with high population densities.

5. Which regions have soils with naturally low fertility?
   - The regions with the lowest fertility are southeastern United States; northeastern South America; southeastern Asia; Australia; and nearly all of Africa.

6. What do these regions have in common?
   - These areas are mainly in the southern hemisphere in tropical areas; they have limited grain production and relatively sparse populations.

7. Which regions have soils that have lost their fertility through overuse? Was the agriculture practiced in these areas sustainable? Explain your answer.
   - Regions that have been overused include southwestern Asia, southern Europe, and parts of Mexico. All of these areas, students may recall from Lesson 1, have had long histories of human habitation and agriculture. This suggests that these ancient practices were not always sustainable in terms of maintaining soil fertility.

8. Which regions are classified as having only *potentially* high fertility? Why aren't these areas very good for farming?
   - Areas that are too dry or cold for agriculture may have potentially fertile soils, but because of the harsh climates, they are unsuitable for farming. Places that have been irrigated can realize this potential. California is a notable example.

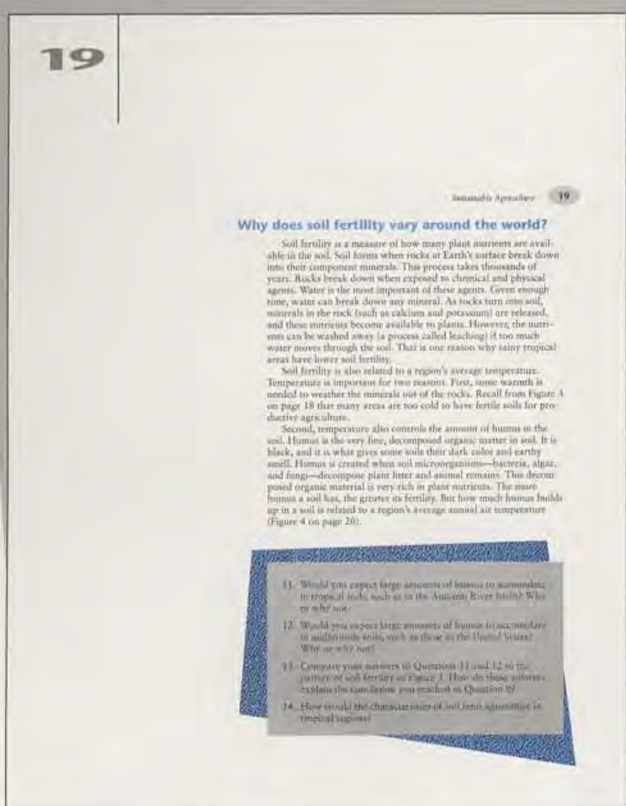
9. Looking at the areas of high and low fertility, what general conclusion can you make about the location (latitude) of these regions?
   - Many generalizations are possible, of course, but the key one here that all groups should see is that *soil fertility is inherently lower in tropical areas than in midlatitude areas.* Some students may have difficulty with the concept of *generalization,* for there are surely exceptions to the pattern (e.g., Nile valley, Java). Clarify that a generalization has exceptions because it is no more than a general statement about the dominant pattern. Subjectivity is always involved; that is part of the process. Encourage students to list areas that do not seem to conform with their generalizations.

continued

10. What climate factor do you think could account for the differences in natural soil fertility that you observed in Question 9? Explain your answer.
    - Students may speculate about possible climatic factors that could account for a latitudinally based pattern. This is designed as a lead-in to the next section. Younger students may skip this question; older students may recognize that temperature is one thing that varies, in a general way, with broad belts of latitude.

Why does soil fertility vary around the world? (pages 19–20)

D. Having discovered the pattern of soil fertility, the next task is to find an explanation. The text and Figure 4 summarize the underlying factors controlling soil fertility. Be sure students understand that greater humus in the soil means greater fertility. Have the groups read this section and discuss Questions 11–14.


19

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Why does soil fertility vary around the world?

Soil fertility is a measure of how many plant nutrients are available in the soil. Soil forms when rocks at Earth's surface break down into their component minerals. This process takes thousands of years. Rocks break down when exposed to chemical and physical agents. Water is the most important of these agents. Given enough time, water can break down any mineral. As rocks turn into soil, minerals in the rock (such as calcium and potassium) are released, and these nutrients become available to plants. However, the nutrients can be washed away (a process called leaching) if too much water moves through the soil. That is one reason why rainy tropical areas have lower soil fertility.

Soil fertility is also related to a region's average temperature. Temperature is important for two reasons. First, some warmth is needed to weather the minerals out of the rocks. Recall from Figure 3 on page 18 that many areas are too cold to have fertile soils for productive agriculture.

Second, temperature also controls the amount of humus in the soil. Humus is the very fine, decomposed organic matter in soil. It is black, and it is what gives some soils their dark color and earthy smell. Humus is created when soil microorganisms—bacteria, algae, and fungi—decompose plant litter and animal remains. This decomposed organic material is very rich in plant nutrients. The more humus a soil has, the greater its fertility. But how much humus builds up in a soil is related to a region's average annual air temperature (Figure 4 on page 20).

11. Would you expect large amounts of humus to accumulate in tropical soils, such as in the Amazon River basin? Why or why not?
12. Would you expect large amounts of humus to accumulate in midlatitude soils, such as those in the United States? Why or why not?
13. Compare your answers to Questions 11 and 12 to the pattern of soil fertility in Figure 3. How do these answers explain the conclusion you reached in Question 9?
14. How would the characteristics of soil limit agriculture in tropical regions?

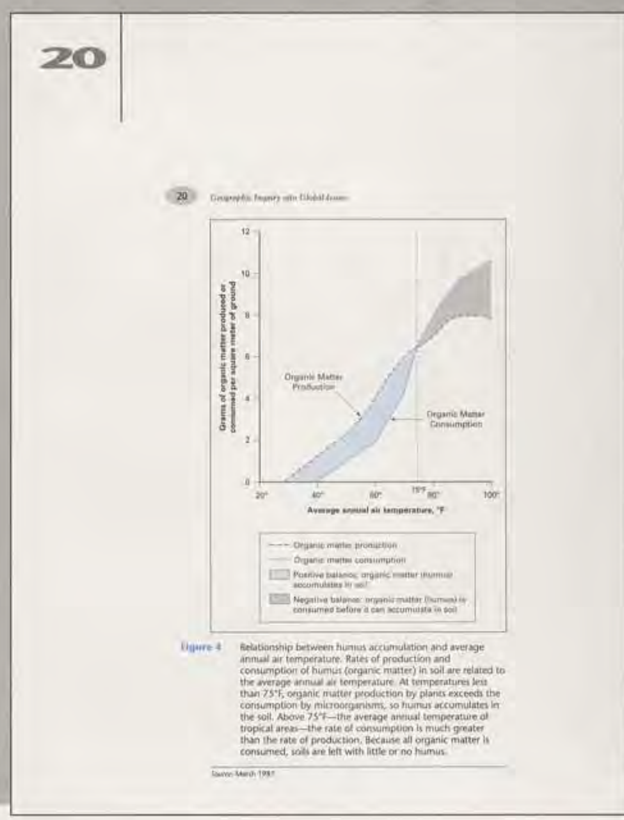


Figure 4 Relationship between humus accumulation and average annual air temperature. Rates of production and consumption of humus (organic matter) in soil are related to the average annual air temperature. At temperatures less than 75°F, organic matter production by plants exceeds the consumption by microorganisms, so humus accumulates in the soil. Above 75°F—the average annual temperature of tropical areas—the rate of consumption is much greater than the rate of production. Because all organic matter is consumed, soils are left with little or no humus.

Source: Marsh 1987

Questions and Answers for page 19

11. Would you expect large amounts of humus to accumulate in tropical soils, such as in the Amazon River basin? Why or why not?
    - Humus would not accumulate in tropical soils because the annual temperature is too high.

12. Would you expect large amounts of humus to accumulate in midlatitude soils, such as those in the United States? Why or why not?
    - Humus would tend to accumulate in midlatitude soils because the temperatures are not warm enough to spur accelerated consumption of organic matter by microorganisms.

13. Compare your answers to Questions 11 and 12 to the pattern of soil fertility in Figure 3. How do these answers explain the conclusion you reached in Question 9?
    - This relationship, as shown in Figure 4, helps account for the generalization made in Question 9, namely, that soil fertility is lower in tropical areas (low humus) than in midlatitude soils (high humus).

14. How would the characteristics of soil limit agriculture in tropical regions?
    - Close the lesson by discussing this question. Focus discussion on the idea that tropical areas simply do not have the capacity to be as productive agriculturally as the midlatitudes. Use care that students do not conclude that agriculture is impossible in these areas. The point is that these areas, with naturally infertile soils, must use different types of agricultural practices than do areas with naturally fertile soils. In other words, decisions about which methods of agriculture to practice in an area must be made with consideration for the local context. Later lessons emphasize that special farming practices are needed to sustain soil fertility in the tropics.

Younger students will probably need to be led carefully through Figure 4. Be sure they understand that if humus consumption exceeds production, then little or no humus can accumulate in the soil. Soils of the tropics thus have few nutrients because of this and because of the leaching of nutrients by heavy rains.

Older students may be curious about some of the exceptions to the general pattern of soil fertility. For example, the Nile valley and the island of Java are both notably more fertile than nearby areas. This is because the soils in these areas are relatively young, so that the nutrients have not been leached out yet. Soils in the Nile valley (and northern India) are replenished by frequent flooding; Java is composed of recently active volcanoes. By the same token, soils in some southern midlatitude areas (Australia, southern Africa) are infertile because they are extremely old (millions of years) and fully depleted of nutrients.

Lesson 4

What is Malaysia like?

Time Required

One 50-minute class period. If your class has already covered the basic geography of Malaysia or Southeast Asia, this lesson can be condensed into a brief review at your discretion.

Materials Needed

Mini-Atlas maps 1, 4, 5, 6, and 7

Glossary Words

East Malaysia

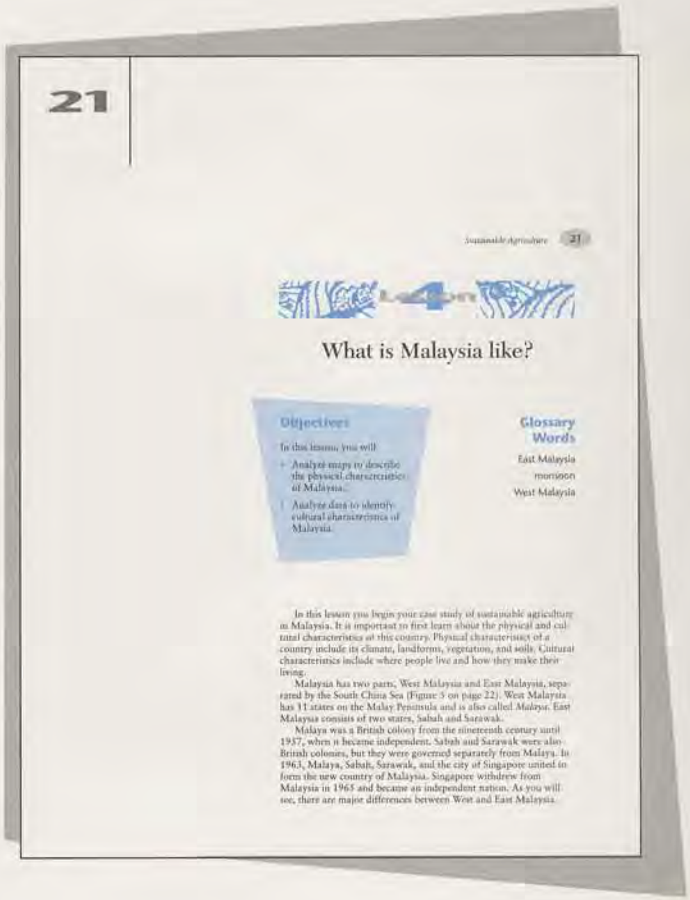
monsoon

West Malaysia

Getting Started

This lesson focuses on the fundamental geographic theme of *place*. Specifically, the lesson provides some background information on the physical and cultural characteristics of Malaysia. To get students thinking about how such characteristics influence our perceptions of a place, ask the class to describe the physical and cultural characteristics of their own community. What is the climate like? The vegetation? The landforms and the soils? How about the characteristics of the human population? What do most people do for a living? Is it a relatively rich or poor community? Do most people live in their own houses or do they rent? What do people do for entertainment? (Clearly there is no end to the types of questions you might ask.)

Have students consider how all of these characteristics define the local context of this place. How is this community similar to or different from other nearby communities? Ask students why knowing about a place is important if one is making plans for its future.


21

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Lesson 4

What is Malaysia like?

Objectives

In this lesson, you will:

- Analyze maps to describe the physical characteristics of Malaysia.
- Analyze data to identify cultural characteristics of Malaysia.

Glossary Words

East Malaysia

monsoon

West Malaysia

In this lesson you begin your case study of sustainable agriculture in Malaysia. It is important to first learn about the physical and cultural characteristics of this country. Physical characteristics of a country include its climate, landforms, vegetation, and soils. Cultural characteristics include where people live and how they make their living.

Malaysia has two parts, West Malaysia and East Malaysia, separated by the South China Sea (Figure 5 on page 22). West Malaysia has 11 states on the Malay Peninsula and is also called *Malaya*. East Malaysia consists of two states, Sabah and Sarawak.

Malaya was a British colony from the nineteenth century until 1957, when it became independent. Sabah and Sarawak were also British colonies, but they were governed separately from Malaya. In 1963, Malaya, Sabah, Sarawak, and the city of Singapore united to form the new country of Malaysia. Singapore withdrew from Malaysia in 1965 and became an independent nation. As you will see, there are major differences between West and East Malaysia.

Procedures

A. Before anything else, write the single word *Malaysia* on the board and ask students to list the physical and cultural characteristics of this place. Allow just a couple of minutes for this brainstorming activity. Students can draw ideas from their own preconceptions, if they have any.

Have students read the short introductory section on Malaysia (page 21), which gives a brief background about the place used as a case study about farming practices. Use Figure 5 on page 22 as a general reference map.

What are Malaysia's physical characteristics? (pages 23–24)

B. Divide the class into pairs or cooperative learning groups of three or four students each. Have groups answer Questions 1–10 after they read the hypothetical letter from the Malaysian exchange student.

Distribute **Mini-Atlas maps 1, 4, 5, 6,** and 7 to answer the questions in this lesson.

If older students find the letter a bit elementary, it can be skipped. Younger students may enjoy writing a similar letter about their own community to a hypothetical exchange student.


23

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What are Malaysia's physical characteristics?

Below is a letter from a young Malaysian named Aldyan, who had been in the United States as an exchange student. Aldyan went back to visit his home country, and he sent this letter from Kuala Lumpur, Malaysia's capital, to a friend in the United States. Aldyan's letter is a good introduction to the land and climate of Malaysia.

Kuala Lumpur, West Malaysia
22 June

Dear Tom:

How is your vacation going? I have really enjoyed coming home to Kuala Lumpur. I like going to school in the United States, but it's always good to come home.

As you might imagine, Kuala Lumpur is very warm. Of course, we live at 3 degrees North latitude, so it's warm all the time.

I never realized how much rain we get until I came back home. It's never that hot here though. That's because it's cloudy most of the time. And the clouds at night keep the evenings warm. Also, because we live near the ocean, it doesn't get too cold here.

Today it was about [illegible] degrees Fahrenheit. It rarely gets hotter than 100 degrees. We spend a lot of time at the beach except during the wet monsoon.

We have the wet monsoon in October and November. It's very windy and it rains all the time. Sometimes we get [illegible] inches of rain in six weeks, and we'll get more than [illegible] inches of rain for the whole year. After a while you just learn to ignore the rain.

Later this week we are going to visit my Uncle Turkman in Sabah. He runs a timber business. The state where he lives is the most rugged in all Malaysia. We have to fly over [illegible] miles to get there, mostly over the ocean.

I wouldn't want to live in Sabah because there are so few people. We have about [illegible] million people in this country and about [illegible] percent live here in Malaya. I like living where there are a lot of people. Most of the people in West Malaysia live on farms.

I have to go now. I hope you have a great vacation. Please write me and tell me what's happening in your town. I'll see you when I come back.

Your friend,
Aldyan Diah

Questions and Answers for page 24

1. Across what range of latitude and longitude is Malaysia located?
   - From Figure 5, one can estimate Malaysia's absolute location as between 0° and 10°N latitude and between 100°E and 120°E longitude.

2. West Malaysia (Malaya) lies on the southern tip of what continent? On what island is East Malaysia (Sarawak and Sabah)?
   - West Malaysia (Malaya) lies on the southern tip of Asia. East Malaysia (Sarawak and Sabah) lies on the island of Borneo.

3. Malaysia has two other independent countries within its borders. Which one is at the tip of Malaya? Which is between Sarawak and Sabah? What other country shares this large island? What other large islands are part of that country?
   - Singapore is at the tip of Malaya; Brunei is between Sarawak and Sabah; Indonesia also shares part of Borneo, as well as parts of the islands of Sumatra, Java, Sulawesi, and Bali (among many others).

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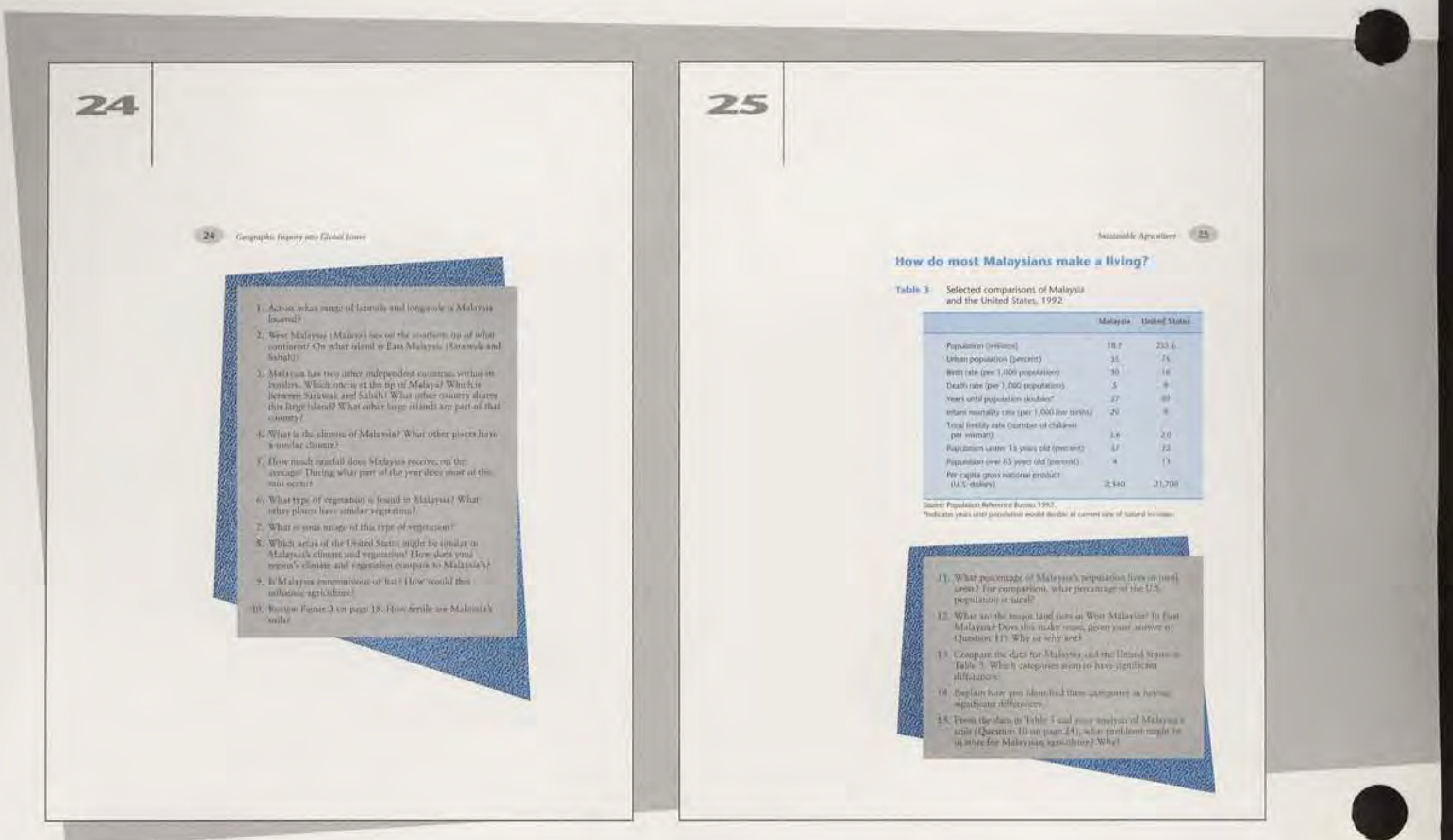

4. What is the climate of Malaysia? What other places have a similar climate?
   - In Mini-Atlas map 1, the climate of Malaysia is classified as *wet equatorial.* Other places with similar climates include Central Africa, the Amazon Basin, and Indonesia.

5. How much rainfall does Malaysia receive, on the average? During what part of the year does most of this rain occur?
   - In Mini-Atlas map 5, Malaysia receives between 80 and 150 inches of rain each year, mostly in October and November.

6. What type of vegetation is found in Malaysia? What other places have similar vegetation?
   - In Mini-Atlas map 4, the vegetation of Malaysia is called *tropical moist forest* or *equatorial rainforest.* Other places with similar vegetation include Central Africa, the Amazon Basin, Indonesia, and Central America.

7. What is your image of this type of vegetation?
   - Answers here will vary, but common (albeit incorrect) terms such as *jungle* may be expected.

8. Which areas of the United States might have climate and vegetation similar to Malaysia? How does your region's climate and vegetation compare to Malaysia's?
   - In the United States, only Hawaii has climate and vegetation similar to Malaysia's. Answers will vary as to how local regions differ; encourage students to list the differences in temperature, precipitation, and vegetation between tropical Malaysia and your own community.

9. Is Malaysia mountainous or flat? How would this influence agriculture?
   - In Mini-Atlas map 6, Malaysia is mainly mountainous, especially East Malaysia. This limits the amount of land usable for farming. (Some sources mention only 3 percent of Malaysia's land as arable.)

10. Review Figure 3. How fertile are Malaysia's soils?
    - Figure 3 classified Malaysia as having naturally low fertility (warm tropical climate, so little humus accumulation).

How do most Malaysians make a living? (page 25)

C. Have groups continue by examining Table 3 and answering Questions 11–15. The data in Table 3 exemplify typical differences between *developing* and *developed* nations. If your class is unfamiliar with these terms, you may need to introduce the idea. Students may better comprehend the concept of developing countries with reference to more familiar examples, such as China, India, or Mexico.

Questions and Answers for page 25

11. What percentage of Malaysia's population lives in rural areas? For comparison, what percentage of the U.S. population is rural?

    - About 65 percent of Malaysia's population lives in rural areas (because 35 percent is shown as urban in Table 3). About 25 percent of the U. S. population is rural.

12. What are the major land uses in West Malaysia? In East Malaysia? Does this make sense, given your answer to Question 11? Why or why not?

    - In Mini-Atlas map 7, West Malaysia is predominantly agricultural. East Malaysia has both agricultural and forestry-related land uses. It should be clear that most Malaysians earn their living from the land, as indicated by the fact that most people live in rural areas.

13–14. Compare the data for Malaysia and the United States in Table 3. Which categories seem to have significant differences? Explain how you identified these categories as having significant differences.

- This asks students to come up with significant differences between Malaysia and the United States. This is deliberately vague: Groups must discuss and reach consensus on what they believe is significant. There are, consequently, no absolute answers here, but students should be prepared to defend their choices. Probably the only category without a large difference is death rate, and possibly also fertility rate. In most cases one country's figures are double or triple the figures in the same category for the other country. This could be a reasonable basis for judging the significance of differences.

15. From the data in Table 3 and your analysis of Malaysia's soils (Question 10), what problems might be in store for Malaysian agriculture? Why?

    - This question calls for speculation; accept any reasonable response. The basic concept here is that a poor country may not have the ability to use the technological means available to improve agricultural productivity.

Lesson 5

Is Malaysia's commercial agriculture sustainable?

Time Required

Three 50-minute class periods

Materials Needed

Butcher paper or poster paper
Rubber band, tub of margarine, piece of tropical wood, rice, and two boxes of cookies, one made with palm oil and one labeled "No Tropical Oils" (optional)
Transparency of Overhead 1

Glossary Words

agricultural system	legumes
arable land	manuring
cash crops	nutrient cycling
commercial agriculture	plant nutrients
East Malaysia	soil
ecosystem	soil fertility
fallow	subsistence agriculture
humus	West Malaysia
leaching	

Getting Started

This lesson forms the detailed case study into Malaysia's agricultural practices. To symbolize Malaysia's principal crops, have the following items laid out for observation as the class enters: some rubber bands (or other rubber products); a tub of margarine or cookies containing tropical oils; a piece of wood (if possible, teak or mahogany); and some rice. Explain to the class that each item relates to the major farm and forestry products of Malaysia. Alternatively, you can arrange to have the students themselves bring in samples of Malaysia's agriculture.

Procedures

Note: This lesson consists of a series of activities interrupted by 19 questions for discussion. You can divide the class into pairs or small groups (three or four students each), as in Lesson 4, and have each group address the questions. Alternatively, you can conduct the discussion with the entire class. Using pairs or small groups, however, will give more students an opportunity to contribute.

How do tropical forest ecosystems work? (pages 26–27)

A. The purpose of this activity is to give students a clearer picture of the context in which Malaysian agriculture must operate. To be sustainable, agricultural methods must be sensitive to the workings of the local physical environment. Ask a few students to read the text in this section aloud. Encourage students to describe forest environments in or near your own community to provide contrast to the tropical systems described.

Many students may have the misconception that tropical soils are fertile, because the popular media portrays the image of the lush rain forests. But one major difference between midlatitude forests and tropical forests is that the latter lacks litter. Be sure students are clear on this, as it may help reinforce the dramatic differences in the way tropical ecosystems work. Review Figure 4 on page 20 if necessary to clarify why tropical soils are nutrient-poor. Have students refer to the Glossary as needed to define unfamiliar terms. Discuss Questions 1–3 now (either in pairs, groups, or with the entire class).

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26 Geographic Inquiry into Global Issues

Lesson 5

Is Malaysia's commercial agriculture sustainable?

Objectives

In this lesson, you will

- Understand how tropical forest ecosystems influence farming practices.
- Identify the main parts of Malaysia's agriculture.
- Describe how agriculture differs between West and East Malaysia.
- Explain how Malaysian farming practices affect the environment.

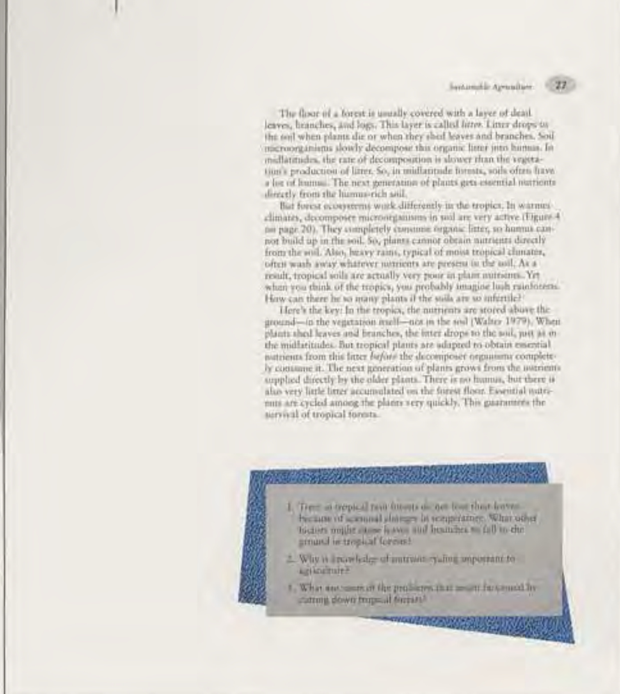
Glossary Words

agricultural system, arable land, cash crops, commercial agriculture, East Malaysia, ecosystem, fallow, humus, leaching, legumes, manuring, nutrient cycling, plant nutrients, soil, soil fertility, subsistence agriculture, West Malaysia

How do tropical forest ecosystems work?

You have seen (Figure 3 on page 18) that natural soil fertility differs between the midlatitudes (such as the mainland United States) and the tropics (such as Southeast Asia). There are also major differences in how plant nutrients move between soils and plants. *Nutrient cycling* refers to the way essential nutrients (including nitrogen, phosphorus, and potassium) flow through an ecosystem. These flows go through soils into plants, from plants to animals, and from one generation of plants to the next. Looking at nutrient cycling is important for understanding the agriculture of tropical countries like Malaysia.

27



Sustainable Agriculture 27

The floor of a forest is usually covered with a layer of dead leaves, branches, and logs. This layer is called *litter*. Litter drops to the soil when plants die or when they shed leaves and branches. Soil microorganisms slowly decompose this organic litter into humus. In midlatitudes, the rate of decomposition is slower than the vegetation's production of litter. So, in midlatitude forests, soils often have a lot of humus. The next generation of plants gets essential nutrients directly from the humus-rich soil.

But forest ecosystems work differently in the tropics. In warmer climates, decomposer microorganisms in soil are very active (Figure 4 on page 20). They completely consume organic litter, so humus cannot build up in the soil. So, plants cannot obtain nutrients directly from the soil. Also, heavy rains, typical of moist tropical climates, often wash away whatever nutrients are present in the soil. As a result, tropical soils are actually very poor in plant nutrients. Yet when you think of the tropics, you probably imagine lush rainforests. How can there be so many plants if the soils are so infertile?

Here's the key: In the tropics, the nutrients are stored above the ground—in the vegetation itself—not in the soil (Walter 1979). When plants shed leaves and branches, the litter drops to the soil, just as in the midlatitudes. But tropical plants are adapted to obtain essential nutrients from this litter *before* the decomposer organisms completely consume it. The next generation of plants grows from the nutrients supplied directly by the older plants. There is no humus, but there is also very little litter accumulated on the forest floor. Essential nutrients are cycled among the plants very quickly. This guarantees the survival of tropical forests.

1. Trees in tropical rain forests do not lose their leaves because of seasonal changes in temperature. What other factors might cause leaves and branches to fall to the ground in tropical forests?
2. Why is knowledge of nutrient cycling important to agriculture?
3. What are some of the problems that might be caused by cutting down tropical forests?

28

28 Geographic Inquiry into Global Issues

What major crops are grown in Malaysia?

Commercial crops, also known as cash crops, can be grown either for domestic use or for export. Cash crops that are exported are important sources of income for countries. All commercial crops are dependent on markets. Like U.S. farmers, farmers in Malaysia grow commercial crops as long as they can earn money from them. If farmers cannot sell certain crops, they must grow other crops that will sell.

Most of Malaysia isn't suitable for farming because of the dense forests, mountainous terrain, and infertile soils. The best agricultural soils in the country are usually on hillsides. In the lowlands, poor drainage can leave places waterlogged, which kills roots.

Table 4 below shows which crops were important exports for Malaysia in 1971 and 1982 (the last year for which complete numbers are available). By the mid-1980s, Malaysian farmers had almost 5 million acres devoted to rubber trees. They had about 3 million acres each planted in rice and oil-palm trees and about 300,000 acres under cultivation for all other crops (Kurian 1987). Export markets for Malaysian products were good, but the Malaysian government wanted the country to be self-sufficient in food production. In 1980, about 22 percent of the total value of exports had to be spent on importing food (Bunge 1985).

Table 4 Exports of principal Malaysian crops, 1971 and 1982

	Amounts produced (thousands of tons) 1971	1982	Percentage of crop exported in 1982
Rubber	1,282	1,378	100
Palm oil products	307	3,904	75
Coconut products	122	89	100
Rice	1,088	1,314	0

Source: Bunge 1985

Questions and Answers for page 27

1. Trees in tropical rain forests do not lose their leaves because of seasonal changes in temperature. What other factors might cause leaves and branches to fall to the ground in tropical forests?
   - Strong winds, heavy rains, or simply the trees aging and dying are other factors causing leaves and branches to fall to the ground in tropical forests.

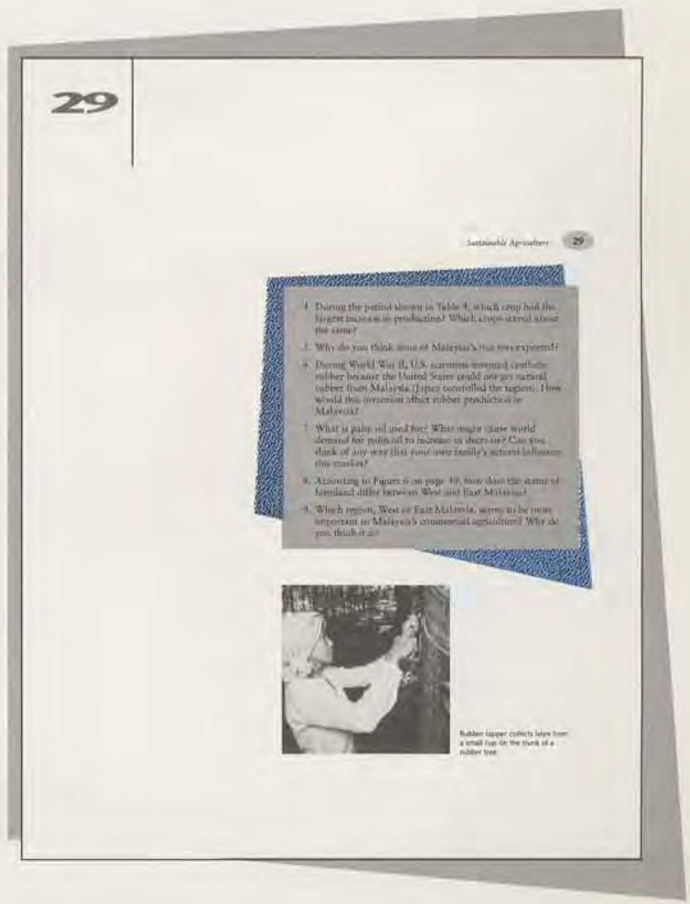
2. Why is knowledge of nutrient cycling important to agriculture?
   - Nutrient cycling is important to understand because one needs to know how and from where plants get essential nutrients. Farmers must use methods to keep soils as rich in nutrients (to maintain fertility) as possible.

3. What are some of the problems that might be caused by cutting down tropical forests?
   - Problems caused by cutting down tropical forests include the interruption of the nutrient cycle and the exposure of soil to erosion.

B. As an optional activity to reinforce these concepts, have student groups sketch the forest nutrient cycling system. The completed drawing ought to look something like **Overhead 1**. Ask students how the nutrient cycle differs between tropical and midlatitude forests. [The flows in the cycle are essentially the same; the critical difference is that the flows are much more rapid in the warm, wet tropical environment.]

What major crops are grown in Malaysia? (pages 28–30)

C. Have groups read the brief text introducing the term *cash crops* and answer Questions 4–9, which are based on Table 4 and Figure 6 (page 30).



Questions and Answers for page 29

4. During the period shown in Table 4, which crop had the largest increase in production? Which crops stayed about the same?
   - Table 4 shows that production of most crops has been stable over the period, except for palm oil, production of which has skyrocketed.

5. Why do you think none of Malaysia's rice was exported?
   - All crops except rice are grown primarily for export. None of the rice is exported because it is needed as a food staple domestically.

6. During World War II, U.S. scientists invented synthetic rubber because the United States could not get natural rubber from Malaysia (Japan controlled the region). How would this invention affect rubber production in Malaysia?
   - If natural rubber can be replaced by synthetic, demand would decline. This influenced farmers to shift to other crops (an example of how world market has dictated Malaysian agricultural choices).

7. What is palm oil used for? What might cause world demand for palm oil to increase or decrease? Can you think of any way that your own family's actions influence this market?
   - This is another example of the importance of the world farm market. For instance, demand for tropical oils has declined because of widely publicized health concerns (namely, cholesterol). Students could ask parents whether they avoid high-cholesterol products such as margarine or cookies made from palm oil.

8. According to Figure 6, how does the status of farmland differ between West and East Malaysia?
   - Figure 6 indicates that, in West Malaysia, nearly all of the land on which cultivation can be developed is being farmed. Very little of the potential agricultural land has been developed in East Malaysia.

9. Which region, West or East Malaysia, seems to be more important to Malaysia's commercial agriculture? Why do you think it is?
   - Based on these data, it is clear West Malaysia is more important to the country's commercial agriculture. This is not surprising given that the vast majority of Malaysians (in a predominantly rural country) live there.

How are Malaysia's major crops grown? (pages 30–34)

D. If you haven't already done so, now divide the class into groups of about four students each. Each group will be responsible for reading and analyzing the information contained in the next four subsections of the Student DataBook: "Rice," "Shifting cultivation," "Rubber," and "Palm oil." Each group need read only the section applying to that group. Groups will each prepare a poster (on butcher or poster paper) detailing their conclusions about whether each of these agricultural systems are sustainable. As there will likely be more than one group per system, you may wish to set up a competition between groups doing the same system to see who comes up with the best effort.

Encourage students to be creative and use visuals to get their points across. Posters should contain the following information:

- Title and students' names.
- A sketch illustrating how each crop is grown.
- Description of changes made to work the land (inputs).
- Discussion of results of changes made to work the land (outputs), including a list of the possible effects of the system on the environment.
- An explanation of how the agricultural system will affect the economy (will it make money?). Here groups need to consider the effect of export and domestic markets on the system.

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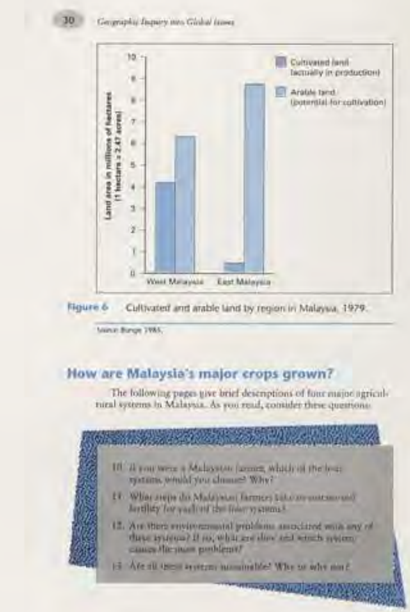

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Land area in millions of hectares (1 hectare = 2.47 acres)

Cultivated land (actually in production)

Arable land (potential for cultivation)

West Malaysia East Malaysia

Figure 6 Cultivated and arable land by region in Malaysia, 1979.

Source: Bunge 1985.

How are Malaysia's major crops grown?

The following pages give brief descriptions of four major agricultural systems in Malaysia. As you read, consider these questions:

10. If you were a Malaysian farmer, which of the four systems would you choose? Why?
11. What steps do Malaysian farmers take to maintain soil fertility for each of the four systems?
12. Are there environmental problems associated with any of these systems? If so, what are they and which system causes the most problems?
13. Are all these systems sustainable? Why or why not?

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Agricultural systems for domestic food

Rice

Rice is the main food of Malaysia. Most of Malaysia's rice is planted in irrigated or flooded fields, known as paddies (this word is derived from the Malay word for rice, *padi*). Most paddies produce two rice crops per year. The best rice farming areas are on the Malay Peninsula. Rice farmers there grow new, higher-yielding breeds of rice, which were developed by scientists. Most rice cultivation in East Malaysia uses dry-land methods, which do not yield as much rice (Bunge 1985).

The most common method of growing rice begins when a paddy to be planted with rice is burned. Then it is flooded and the vegetation left to rot. The field is plowed several times to mix the rotting vegetation in order to resupply the soil with nutrients. Rice seedlings are brought in from a nursery. They are planted in two inches of water. The water helps prevent weed growth. Later, when the leafy adult plants create too much shade for weeds to grow, the fields are drained. Rice is harvested in the dry season so it can be dried before being milled. Manure is spread if necessary to replace lost soil nutrients.

Rice is grown entirely for use within Malaysia. Nearly all of Malaysia's domestic needs for rice are met by small landholders, but 10 percent of the country's rice must be imported from Thailand. World prices for rice are usually quite low, so a farmer can make more from an acre of rubber or oil-palm trees than from rice. However, rice is always in demand because it is the main food consumed by Malaysians (Ooi Jin-Bee 1976).

Shifting cultivation

In 1980, the U.N. Food and Agriculture Organization estimated that about 1.7 million people in Sabah and Sarawak relied on *shifting cultivation*. Only about 50,000 people in West Malaysia also still use this ancient system of raising food (Bunge 1985). Most shifting cultivators don't produce commercial crops sold on the market. Rather, they grow only enough food for their own families and communities. This is known as subsistence agriculture.

Under shifting cultivation, only about 10 percent of the land is actually farmed in any given year. The remainder is left fallow (no crops planted), allowing natural vegetation to grow. A plot of land is cropped for a year or two, then left alone for at least 10 years while the vegetation recovers. Then the farmer burns the vegetation, enriching the soil's fertility with the ashes. Crops are then planted for

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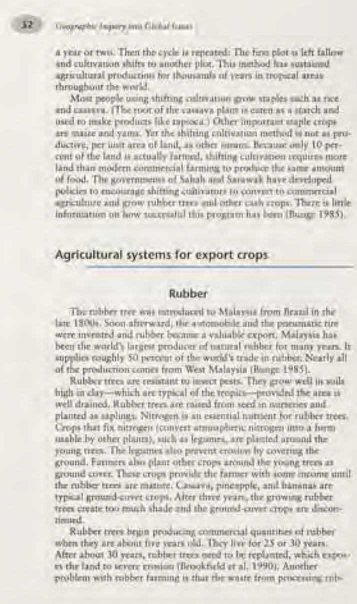

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a year or two. Then the cycle is repeated: The first plot is left fallow and cultivation shifts to another plot. This method has sustained agricultural production for thousands of years in tropical areas throughout the world.

Most people using shifting cultivation grow staples such as rice and cassava. (The root of the cassava plant is eaten as a starch and used to make products like tapioca.) Other important staple crops are maize and yams. Yet the shifting cultivation method is not as productive, per unit area of land, as other systems. Because only 10 percent of the land is actually farmed, shifting cultivation requires more land than modern commercial farming to produce the same amount of food. The governments of Sabah and Sarawak have developed policies to encourage shifting cultivators to convert to commercial agriculture and grow rubber trees and other cash crops. There is little information on how successful this program has been (Bunge 1985).

Agricultural systems for export crops

Rubber

The rubber tree was introduced to Malaysia from Brazil in the late 1800s. Soon afterward, the automobile and the pneumatic tire were invented and rubber became a valuable export. Malaysia has been the world's largest producer of natural rubber for many years. It supplies roughly 50 percent of the world's trade in rubber. Nearly all of the production comes from West Malaysia (Bunge 1985).

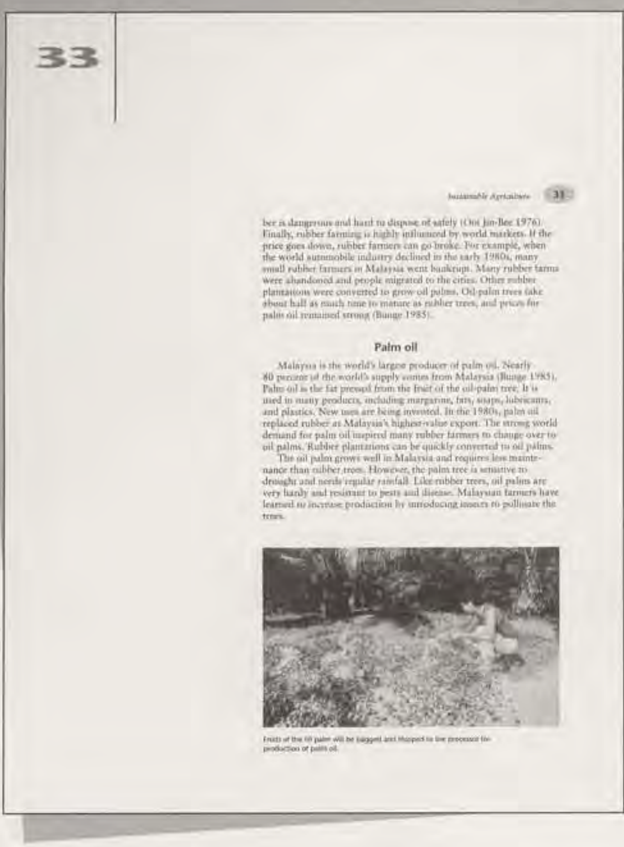
Rubber trees are resistant to insect pests. They grow well in soils high in clay—which are typical of the tropics—provided the area is well drained. Rubber trees are raised from seed in nurseries and planted as saplings. Nitrogen is an essential nutrient for rubber trees. Crops that fix nitrogen (convert atmospheric nitrogen into a form usable by other plants), such as legumes, are planted around the young trees. The legumes also prevent erosion by covering the ground. Farmers also plant other crops around the young trees as ground cover. These crops provide the farmer with some income until the rubber trees are mature. Cassava, pineapple, and bananas are typical ground-cover crops. After three years, the growing rubber trees create too much shade and the ground-cover crops are discontinued.

Rubber trees begin producing commercial quantities of rubber when they are about five years old. They live for 25 or 30 years. After about 30 years, rubber trees need to be replanted, which exposes the land to severe erosion (Brookfield et al. 1990). Another problem with rubber farming is that the waste from processing rub-

- A tentative decision whether the agricultural system is sustainable or not. Here groups should consider how their system deals with water, soil, and fossil fuel resources. Groups can try to determine whether these resources are being "mined" (unsustainable) or not (sustainable). ***Important:*** Some of this information will not be available until other data are presented later in this lesson. Have groups make tentative decisions now, subject to review later.

To get information needed for the posters, students will need to read the relevant page about rice, shifting cultivation, rubber, and palm oil (pages 31–34). As they read, they should consider Questions 10–13 (page 30). Allow one day of class time for this phase of the lesson. Have groups present their posters to the rest of the class, describing the agricultural systems and their conclusion about sustainability. There are no "correct" conclusions, but groups should be able to defend their tentative decision based on the available information.

Extra guidance may be needed for younger students. Have the groups make a poster, with a picture or sketch of the product and its name. Students can then use pictures or words to represent four facts about the farming practices for that product. Groups should then present their posters to the rest of the class. Use class discussion then to decide whether or not the practices are sustainable.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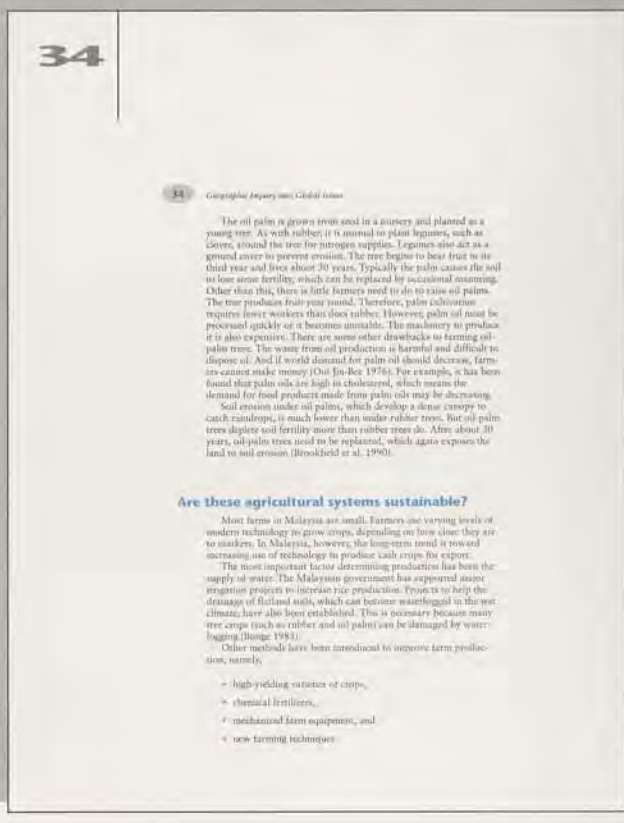
ber is dangerous and hard to dispose of safely (Ooi Jin-Bee 1976). Finally, rubber farming is highly influenced by world markets. If the price goes down, rubber farmers can go broke. For example, when the world automobile industry declined in the early 1980s, many small rubber farmers in Malaysia went bankrupt. Many rubber farms were abandoned and people migrated to the cities. Other rubber plantations were converted to grow oil palms. Oil-palm trees take about half as much time to mature as rubber trees, and prices for palm oil remained strong (Bunge 1985).

Palm oil

Malaysia is the world's largest producer of palm oil. Nearly 80 percent of the world's supply comes from Malaysia (Bunge 1985). Palm oil is the fat pressed from the fruit of the oil-palm tree. It is used in many products, including margarine, fats, soaps, lubricants, and plastics. New uses are being invented. In the 1980s, palm oil replaced rubber as Malaysia's highest-value export. The strong world demand for palm oil inspired many rubber farmers to change over to oil palms. Rubber plantations can be quickly converted to oil palms.

The oil palm grows well in Malaysia and requires less maintenance than rubber trees. However, the palm tree is sensitive to drought and needs regular rainfall. Like rubber trees, oil palms are very hardy and resistant to pests and disease. Malaysian farmers have learned to increase production by introducing insects to pollinate the trees.

Fruits of the oil palm will be bagged and shipped to be processed for production of palm oil.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The oil palm is grown from seed in a nursery and planted as a young tree. As with rubber, it is normal to plant legumes, such as clover, around the tree for nitrogen supplies. Legumes also act as a ground cover to prevent erosion. The tree begins to bear fruit in its third year and lives about 30 years. Typically the palm causes the soil to lose some fertility, which can be replaced by occasional manuring. Other than this, there is little farmers need to do to raise oil palms. The tree produces fruit year round. Therefore, palm cultivation requires fewer workers than does rubber. However, palm oil must be processed quickly or it becomes unstable. The machinery to produce it is also expensive. There are some other drawbacks to farming oil-palm trees. The waste from oil production is harmful and difficult to dispose of. And if world demand for palm oil should decrease, farmers cannot make money (Ooi Jin-Bee 1976). For example, it has been found that palm oils are high in cholesterol, which means the demand for food products made from palm oils may be decreasing.

Soil erosion under oil palms, which develop a dense canopy to catch raindrops, is much lower than under rubber trees. But oil-palm trees deplete soil fertility more than rubber trees do. After about 30 years, oil-palm trees need to be replanted, which again exposes the land to soil erosion (Brookfield et al. 1990).

Are these agricultural systems sustainable?

Most farms in Malaysia are small. Farmers use varying levels of modern technology to grow crops, depending on how close they are to markets. In Malaysia, however, the long-term trend is toward increasing use of technology to produce cash crops for export.

The most important factor determining production has been the supply of water. The Malaysian government has supported major irrigation projects to increase rice production. Projects to help the drainage of flatland soils, which can become waterlogged in the wet climate, have also been established. This is necessary because many tree crops (such as rubber and oil palm) can be damaged by waterlogging (Bunge 1985).

Other methods have been introduced to improve farm production, namely,

- high-yielding varieties of crops,
- chemical fertilizers,
- mechanized farm equipment, and
- new farming techniques

Questions and Answers for page 30

10. If you were a Malaysian farmer, which of the four systems would you choose? Why?
    - Answers here will vary. The key point is how markets influence farmers' choices to grow rice, rubber, or palm oil. Note that rice isn't as lucrative as rubber or palm, but both of those crops are subject to fluctuating demand on the international market. Rice, being the domestic staple, is always in demand.

11. What steps do Malaysian farmers take to sustain soil fertility for each of the four systems?
    - *Rice:* burned and rotting vegetation mixed in with soil to provide organic matter.

      Shifting cultivation: fallow periods give soil a chance to recover from cropping. Burning vegetation adds organic matter to soil.

      Rubber: nitrogen-fixing crops grown; also prevent erosion.

      Palm oil: nitrogen-fixing crops grown; also prevent erosion. Manure added to replace lost nutrients.

12. Are there environmental problems associated with any of these systems? If so, what are they and which system causes the most problems?
    - Waste from processing rubber and palm oil pollutes the environment. Soil erosion is also mentioned as a problem for these crops.

13. Are all these systems sustainable? Why or why not?
    - At this point in the lesson, groups' answers will be somewhat speculative, so accept any reasonable response. More data is provided in the final section of the lesson.

Are these agricultural systems sustainable? (pages 34–38)

E. This section contains additional data that groups can use as they discuss whether the farming methods are sustainable. Prior to dividing the class back into their groups, it may be useful to focus some class discussion on the text preceding Figure 7 on page 35. Students can note that agricultural production is being supported by large-scale irrigation projects. In addition, the text notes that Malaysia is becoming increasingly dependent on conventional methods of agriculture, including the heavy use of chemical fertilizers. This may open up the question of whether these practices are sustainable in the long run.

   Figure 7 shows three aspects of agriculture: the outputs (food production per capita); the inputs (fertilizer consumption); and dependency (imports of cereal grains). Students may note that food production has been increasing, primarily because of the large increase in fertilizer use. Nevertheless, Malaysia has still had to approximately triple its imports of food staples (i.e., cereals). Together, these trends suggest that Malaysian agriculture may not be sustainable. These data are only part of the story, but clearly more domestic food production is needed so the country can be self-sufficient.

F. Have the students return to their groups to analyze Tables 5 and 6 and Figures 7–9 to come to some final decision regarding the sustainability of their crop or method. Again, there is no one correct solution to this problem; different conclusions are possible. Have each group answer Questions 14–19.

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Some results of these programs are shown in Figure 7 below. Which of these trends seem to be sustainable? Which do not? Additional data (Figures 7–9 and Tables 5–6) are presented on pages 35–38 to help you consider whether or not commercial farming in Malaysia is sustainable.

Review these data and the information from the readings in this lesson. Decide whether or not Malaysia is, in effect, "mining" its soils, water, and fossil fuel resources to support its commercial agriculture.

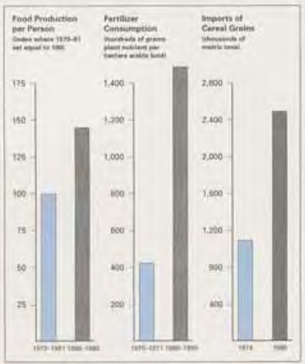

Figure 7 Trends in Malaysian agriculture, 1970s to 1990s.

Source: World Bank 1992.

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Table 5 Population projections for Malaysia to 2025

Year	Population estimate (millions)
1992	18.7
2010	27.1
2025	34.9

Source: Population Reference Bureau 1992.

Table 6 Malaysia's production and exports of petroleum, 1971 and 1983 (thousands of barrels of oil)

	1971	1983
Production	11,672	139,284
Exports	5,566	102,957

Source: Bunge 1985.

In 1950, tropical forests covered about 73 percent of the Malay Peninsula (Brookfield et al. 1990). Since then, much of the forest has been cleared for agriculture, mainly to grow oil palm and rubber (Figure 8 on page 37). Although logging has been destructive, converting forests to plantations has created much wealth, both for

Malaysian rain forest cleared for rubber plantation.

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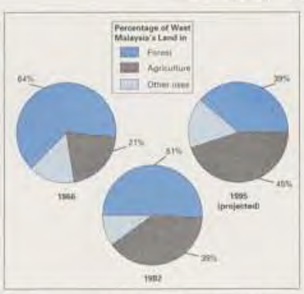

Figure 8 Conversion of forest land to agriculture in West Malaysia, 1966 to 1995.

Source: Brookfield et al. 1990.

foreign investors and for many Malaysians. This fact needs to be remembered when looking at the environmental changes that have occurred.

The loss of forest cover means that the few nutrients in the soil can be leached away. Also, removing the forest cover makes soil prone to erosion from the heavy rains. Erosion is a serious problem in many ways. Eroded soil washes into streams, raising the level of the riverbed. This process is called siltation (Figure 9 on page 38). During the rainy season, the shallower rivers cannot handle the higher stream-flow, and severe floods can occur. In the dry season, there may not be enough water in the stream to flow through the silt deposits. This has led to water shortages in some communities (Brookfield et al. 1990).

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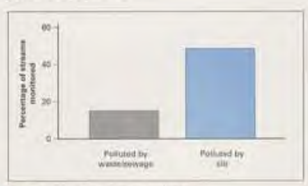


Figure 9 Sources of stream pollution in Malaysia.

Source: Sani 1988.

14. Why are population data (Table 5 on page 36) important for thinking about agricultural sustainability?
15. Why are data for petroleum (Table 6 on page 36) helpful for considering whether modern farming practices are sustainable?
16. What would be a good way to draw or describe the increases in production and export of petroleum from 1971 to 1983? Why?
17. Which pollutes more streams, sewage or silt (Figure 9 above)? Why is silt considered a pollutant? What environmental damage does silt cause?
18. What causes silt pollution in Malaysia? How is this related to the issue of sustainable agriculture?
19. Did your opinion about whether Malaysia's farming practices are sustainable change as a result of looking at these data? Why or why not?

Questions and Answers for page 38

14. Why are population data (Table 5) important for thinking about agricultural sustainability?
    - The population data show that agricultural production will have to greatly increase to feed the near-doubling of population in the next 30 years.

15. Why are data for petroleum (Table 6) helpful for considering whether modern farming practices are sustainable?
    - Chemical fertilizers are made from petroleum. Table 6 indicates that Malaysia has recently increased its crude oil production. It would seem that Malaysia need not be concerned about dependence on a foreign or scarce resource.

16. What would be a good way to show or describe the increases in production and export of petroleum from 1971 to 1983? Why?
    - A bar graph would show the big increases well. Other answers are possible. A simple verbal description: Production is more than 10 times greater; exports are more than 20 times greater.

17. Which pollutes more streams, sewage or silt (Figure 9)? Why is silt considered a pollutant? What environmental damage does silt cause?
    - Silt pollutes more streams. It is considered a pollutant because it raises the riverbed, causing flooding and shortages of water supplies. Also, silty water is undrinkable.

18. What causes silt pollution in Malaysia? How is this related to the issue of sustainable agriculture?
    - River silt is eroded soil, most of which is washed off of slopes deforested to make room for cash crops, especially rubber and palm oil. Soil losses of this magnitude are unsustainable, because soil takes thousands of years to form.

19. Did your opinion about whether Malaysia's farming practices are sustainable change as a result of looking at these data? Why or why not?
    - Answers here will vary by group. See Procedure G below.

G. Close the lesson by having the class discuss if any of the four agricultural systems represents a major threat to Malaysia's environment. Encourage the class to seek a consensus regarding the lesson question: Is Malaysian commercial agriculture sustainable? [Conclusions will, of course, vary, depending on each group's opinions. It may be, however, that students will see the increasing reliance on fossil fuels in Malaysia as a potential problem. Diversion of water resources for irrigation projects and water pollution from chemicals and silt may present problems in the future. How Malaysia can develop self-sufficiency in food production, if production is geared toward exported cash crops, represents another problem. In addition, processing rubber and palm oil can pollute the environment. On the plus side, many farmers in Malaysia are clearly sensitive to the need to maintain soil fertility. Use of legumes to retard erosion and add nitrogen to the soil represents a very sustainable practice. And techniques of shifting cultivation can help maintain productivity. Finally, Malaysia currently appears to have sufficient petroleum resources to warrant some dependence on chemical fertilizers.]

For Further Inquiry

Have students write an essay concerning the question of sustainability of Malaysia's commercial agriculture, perhaps written as a newspaper editorial complete with pictures from a magazine or a personal drawing, which can be used to assess the understanding of individuals or groups of students.

Lesson 6

Can agriculture in Africa be made sustainable?

Time Required

One or two 50-minute class periods

Materials Needed

Copies of Activity 3 for all students

Glossary Words

agroforestry

doubling time

fallow

humus

nitrogen fixation

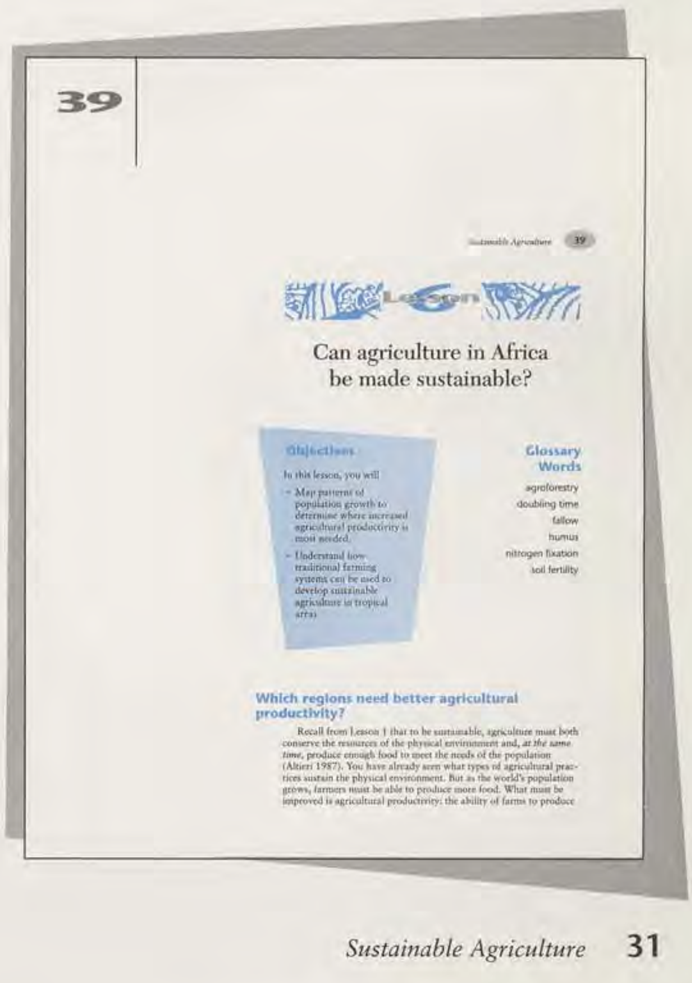
soil fertility

Procedures

Which regions need better agricultural productivity? (pages 39–41)

A. Ask students to read the text introducing Table 7 (pages 39–40). Be sure students understand the meaning of *doubling time.* To check understanding, ask whether a high doubling time (many years) means a low or high population growth rate (in case students are confused by the idea of a high number meaning a low rate, and vice versa).

Distribute copies of **Activity 3** to each student. Have students map the doubling-time data from Table 7 onto the Activity. The result (see *Key for Activity 3*) will show the regional variation in population growth rates. When completed, Activity 3 represents a type of map known as a *choropleth* (or *area-value*) map, in which different shades are used to show relative values. As a rule, darker shades show higher values of the phenomenon and lighter shades show lower values. (For example, a typical choropleth map might show per capita income, with richer countries given darker shades and poorer countries lighter shades.)



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Lesson 6

Can agriculture in Africa be made sustainable?

Objectives

In this lesson, you will

- Map patterns of population growth to determine where increased agricultural productivity is most needed.
- Understand how traditional farming systems can be used to develop sustainable agriculture in tropical areas.

Glossary Words

agroforestry

doubling time

fallow

humus

nitrogen fixation

soil fertility

Which regions need better agricultural productivity?

Recall from Lesson 3 that to be sustainable, agriculture must both conserve the resources of the physical environment and, *at the same time*, produce enough food to meet the needs of the population (Altieri 1987). You have already seen what types of agricultural practices sustain the physical environment. But as the world's population grows, farmers must be able to produce more food. What must be improved is agricultural productivity: the ability of farms to produce

Note that Activity 3 defines three categories for mapping (doubling times less than 50 years; between 50–100 years; and greater than 100 years). It is left up to the student to decide what kind of shading to use to represent the regions in each category. Because the doubling-time values are used to show population growth, it makes sense to use darker shades for low doubling times (high growth); lighter shades (or no shade at all) for high doubling times (low growth); and a medium shade for the middle group. This is what the *Key for Activity 3* does. Once students have completed Activity 3, discuss Questions 1–5.

If younger students are confused by the relationship of the variable (doubling time) to population growth, you may wish to tell them which shading to use. This limits the exercise to filling in the appropriate shades for each region.

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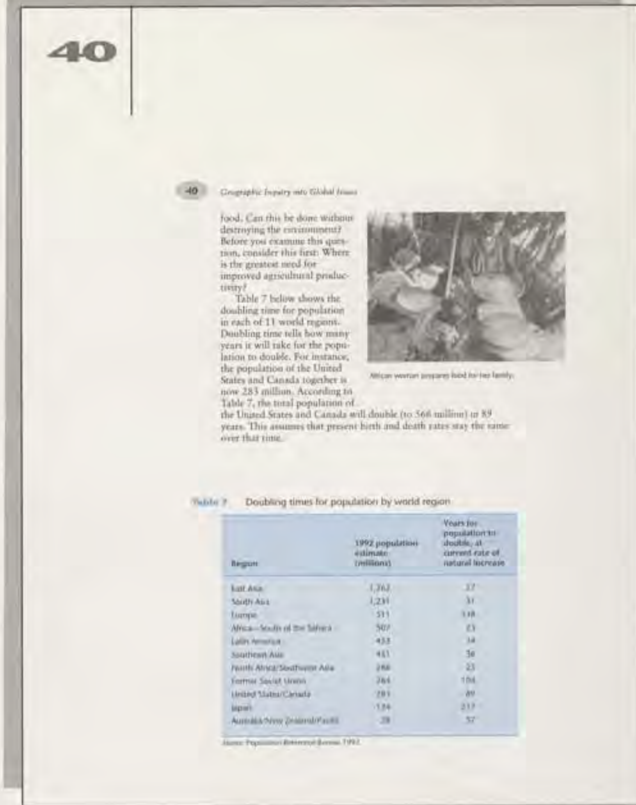

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food. Can this be done without destroying the environment? Before you examine this question, consider this first: Where is the greatest need for improved agricultural productivity?

Table 7 below shows the doubling time for population in each of 11 world regions. Doubling time tells how many years it will take for the population to double. For instance, the population of the United States and Canada together is now 283 million. According to Table 7, the total population of the United States and Canada will double (to 566 million) in 89 years. This assumes that present birth and death rates stay the same over that time.

African woman prepares food for her family.

Table 7 Doubling times for population by world region

Region	1992 population estimate (millions)	Years for population to double, at current rate of natural increase
East Asia	1,262	37
South Asia	1,231	31
Europe	511	118
Africa—South of the Sahara	507	23
Latin America	453	34
Southeast Asia	451	36
North Africa/Southwest Asia	288	23
Former Soviet Union	284	104
United States/Canada	283	89
Japan	124	217
Australia/New Zealand/Pacific	28	57

Source: Population Reference Bureau 1992.

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Sustainable Agriculture 41

1. How is population growth related to the need for greater agricultural productivity?
2. Which areas are growing faster: those with a low doubling time, or those with a high doubling time?
3. Compare the pattern of doubling time to the pattern of world soil fertility (Figure 3 on page 18). Which areas have both rapid population growth and poor soils?
4. Why would these areas have the greatest problem in improving agricultural productivity?
5. What is the problem with grouping data on population growth by region, as is done in Table 7? What additional kinds of information might be important to have?

How can productivity be increased in tropical areas?

Recently, scientists have realized that tropical farming systems that were used for thousands of years must have managed soil, water, and nutrient resources carefully. In other words, traditional methods of tropical agriculture may provide techniques to make modern farming sustainable (Wolf 1987).

In tropical areas with nutrient-poor soils, intensive monocropping quickly robs soil of its fertility. Instead, farmers must plant a variety of crops and rotate these crops. This method allows essential nutrients enough time to be renewed. Traditionally, shifting cultivation used this approach. But shifting cultivation requires large amounts of land. Often rapid population growth forces farmers to return too soon to fallow fields or forces them onto marginal lands. When this happens, shifting cultivation can cause major environmental damage.

African scientists have adapted the principles of shifting cultivation to modern conditions. This technique is known as agroforestry. Agroforestry maintains forests, renews soil fertility, and yields more food than traditional shifting cultivation (Wolf 1987).

The basics of agroforestry are simple. Field crops are grown between rows of nitrogen-fixing trees. Tree crops, such as oil palms,

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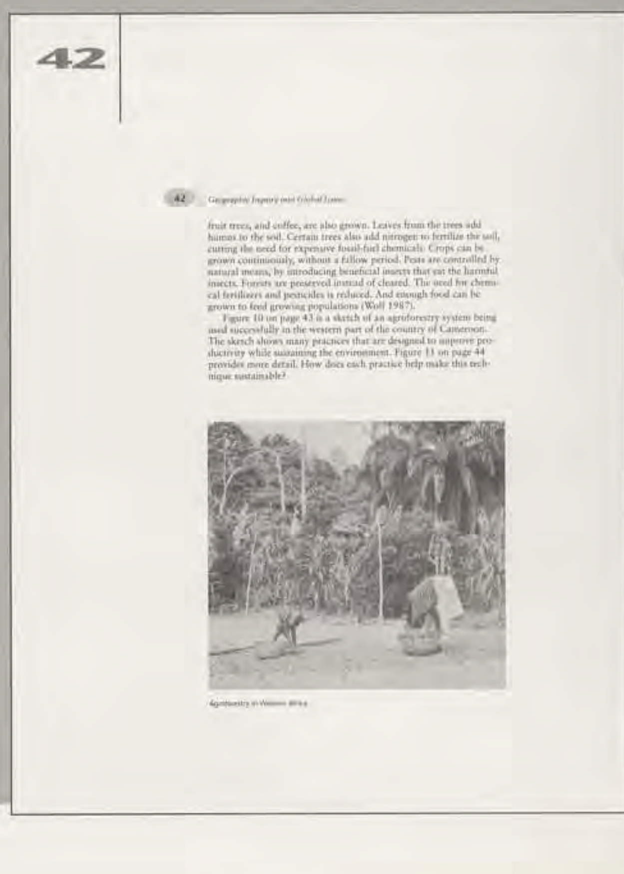

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fruit trees, and coffee, are also grown. Leaves from the trees add humus to the soil. Certain trees also add nitrogen to fertilize the soil, cutting the need for expensive fossil-fuel chemicals. Crops can be grown continuously, without a fallow period. Pests are controlled by natural means, by introducing beneficial insects that eat the harmful insects. Forests are preserved instead of cleared. The need for chemical fertilizers and pesticides is reduced. And enough food can be grown to feed growing populations (Wolf 1987).

Figure 10 on page 43 is a sketch of an agroforestry system being used successfully in the western part of the country of Cameroon. The sketch shows many practices that are designed to improve productivity while sustaining the environment. Figure 11 on page 44 provides more detail. How does each practice help make this technique sustainable?

Agroforestry in Western Africa

Questions and Answers for page 41

1. How is population growth related to the need for greater agricultural productivity?
   - Areas with rapid population growth need to increase agricultural productivity to feed their increasing populations.

2. Which areas are growing faster: those with a low doubling time, or those with a high doubling time?
   - This question reinforces the basic relationship noted earlier: Areas with a low doubling time are actually growing faster.

3. Compare the pattern of doubling time to the pattern of world soil fertility (Figure 3). Which areas have both rapid population growth and poor soils?
   - Areas with both rapid growth and infertile soils are the world's tropical areas, including Southeast Asia, sub-Saharan Africa, and most of Latin America.

4. Why would those areas have the greatest problem in improving agricultural productivity?
   - Rapid population growth necessitates growing more food, but it is clear that there are limits to what the soils of these regions can produce. This represents the fundamental agricultural problem of these regions.

5. What is the problem with grouping data on population growth by region, as is done in Table 7? What additional kinds of information might be important to have?
   - Data grouped by region masks differences within the regions. For instance, populations of some of the new countries of the former Soviet Union are actually doubling as fast as the populations of countries in Africa and Latin America. In order to detect differences within these large regions, one would need data for the individual countries.

How can productivity be increased in tropical areas? (pages 41–44)

B. This section of the lesson uses a case study from Africa to show how traditional farming methods have been updated to create sustainable agricultural systems. Have students read the text on pages 41–42, and discuss with the class why it makes sense to adapt ancient methods of farming to modern conditions. One important theme mentioned by people promoting sustainable agriculture is that local conditions (local soils, local crops, local methods, local customs) must form the backbone of agricultural planning.

   To get the point across, you might ask how students would feel if an entirely different economic system were thrust upon them without any consideration for local traditions. In fact, past agricultural planning for much of the developing world did just that. Methods and systems used in the midlatitudes were attempted in tropical countries, but the success of these programs was very limited. Ask students why it is unlikely that midlatitude farming systems would work in the tropics. [The differences in soil conditions (humus, etc.)]

C. Have students locate Cameroon on a world map. Emphasize its tropical locale. Divide the class into groups of two or three students and ask these groups to examine Figures 10 and 11 on pages 43 and 44. Tell the class that these are sketches of an agricultural system used with success in Cameroon. It is an approach that is both sustainable and that has increased food productivity. Have groups attempt to describe (in very short sentences) why each of the practices shown in Figures 10 and 11 is sustainable. See the following *Background Note* for help with answering student questions.

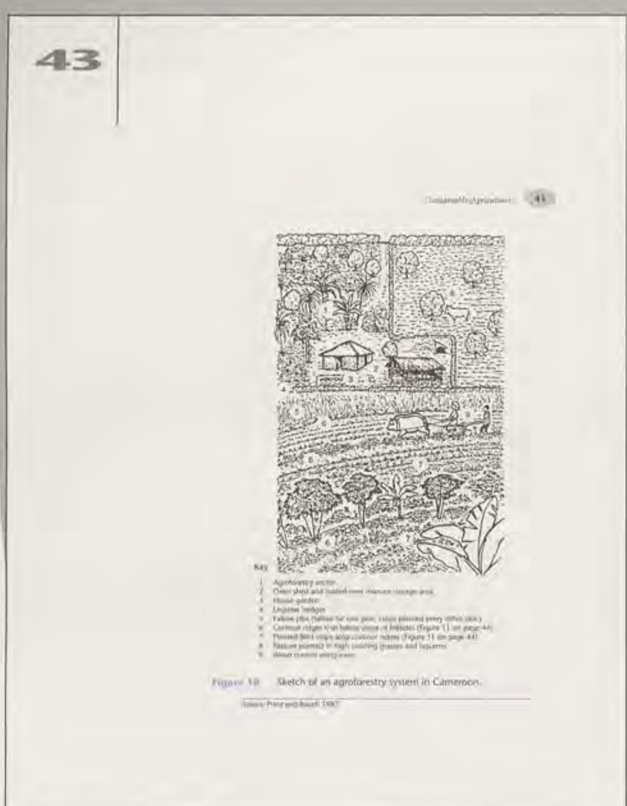
Background Note

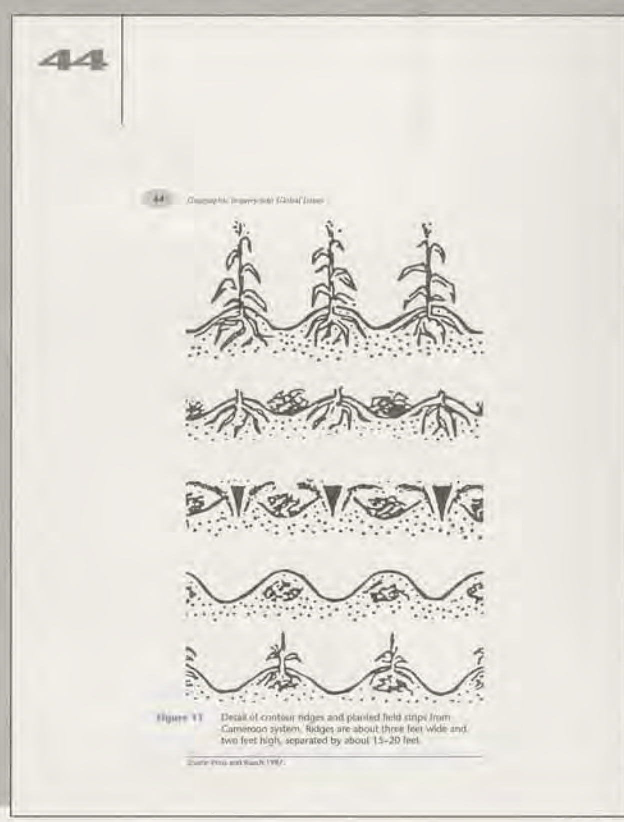
Agroforestry System in Cameroon

1. *Agroforestry* (trees mixed with field crops): Trees fix nitrogen and provide cash crops, such as palm oil, coffee, and fruit. Nitrogen-fixing trees fertilize soil.
2. *Oxen shed/manure storage area:* Oxen provide farm labor and their manure can be used as a fertilizer. Oxen graze outside during the day but are kept indoors at night so their manure can be gathered.
3. *House garden:* Area set aside for vegetables and other crops used by the family. Cuts reliance on outside sources of food.
4. *Legume hedges:* Crops that fix nitrogen to fertilize soil. Cuts reliance on chemical fertilizers (used along with natural fertilizers such as oxen manure).
5. *Fallow plot:* Allows soil time to recover between cropping periods.

6–7. *Contour ridges and planted field strips:* Ridges, by following slopes, cut down on soil erosion. They also conserve water by holding it in furrows, right next to crops planted on the ridge. Ridges can be planted in high-yield crops, such as corn, because they have higher humus. Figure 11 shows why: One year's furrows become next year's ridges. Organic residues from old crops are used to fill in the furrows to create the ridge. Ridges thus maintain high humus content and fertility. Cycle can be repeated indefinitely.

8. *Pasture:* Provides grazing area for oxen to keep farm self-sufficient. High-yielding grasses mean less area needs to be set aside for pastures; legumes keep the soil rich in nitrogen.
9. *Weed control:* Using oxen to trample weeds cuts need to use chemical weed killers.



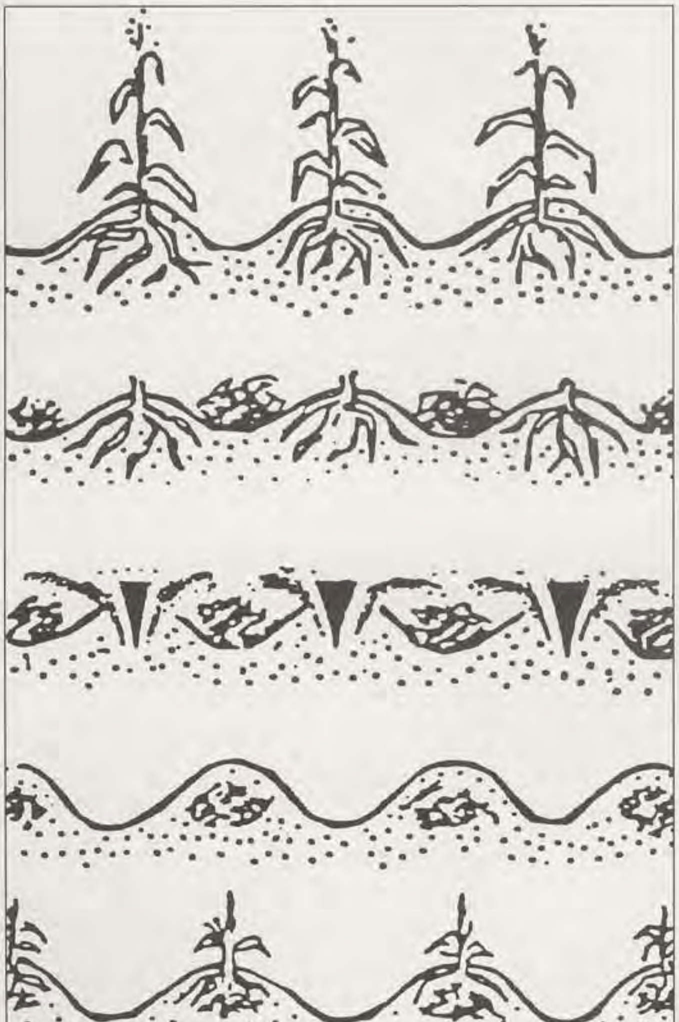


D. If time permits, close the lesson by asking if this kind of approach solves the problem of unsustainable agriculture. Students may well wonder why more places don't come up with such systems, appropriate to their local conditions. The key is that establishing such programs requires money and support. Not all countries can afford the types of training involved to teach farmers how to use these types of systems. More critically, perhaps, support from government agencies is lacking. Many international agencies are reluctant to rely on traditional methods, preferring to try to import midlatitude methods to tropical conditions (Wolf 1987). One important conclusion of this activity might be that changing agricultural practices requires the active encouragement of government and industry.

For Further Inquiry

Assign an essay asking students to discuss why agricultural planning needs to consider local conditions and traditions to be successful.

Share with students the labels shown below that explain the diagrams in Figure 11.



1. Crops are grown on the ridges during the rainy season.
2. After the harvest, the furrows between ridges are filled with crop residues and manure.
3. Ridges are split open; soil from ridges used to bury the organic matter in furrows.
4. During the dry season, the organic matter, now under new ridges, decomposes into humus.
5. Next rainy season, new crops are cultivated on these new ridges.

Is conventional farming in the western United States sustainable?

Time Required

Two or three 50-minute class periods

Materials Needed

Copies of Activity 4 for all students
Mini-Atlas map 1

Glossary Words

aquifer	monocropping
cash crops	nonrenewable resource
fodder	pesticide
herbicide	soil
legumes	topsoil
marginal land	

Getting Started

- Students should be aware that the United States and Canada are major world food producers. Ask students why the midlatitudes of North America are so productive. [Students may recall the high inherent soil fertility of the region, as shown on Figure 3 on page 18]. Have a student point out the major agricultural zone on a wall map of the United States. [The Midwest] Ask the class if they think that most farms in the United States are using sustainable methods. See if students can guess the percentage of U.S. farms that practice sustainable agriculture. [They may be surprised that only 3 percent of farms do.]

- Inform the class that they will next look at the problems agriculture faces in the drier half of this country—the West. You might note that many of the problems noted earlier in the module, such as dependence on fossil fuels for fertilizers and energy, occur throughout the country. The aridity of the West, however, poses some special problems.

  If younger students do not know that the climate gets drier as one goes west in the United States (until one reaches the Pacific coast), have them use **Mini-Atlas map 1** of world climates to note that lands in North America west of 100°W longitude receive less than 20 inches of precipitation per year.

Procedures

What environmental problems does farming cause on arid western lands? (pages 45–48)

A. Ask why agriculture in arid lands might need special techniques to avoid wind erosion. Using a small container of any dry soil (which can be obtained in advance from the schoolyard and allowed to dry out), you can demonstrate the problem readily. Blow on the soil to show how easily wind can erode dry soil. Then discuss what could be done to the soil to prevent wind erosion. [Answers include keeping the soil moist or planting something to hold the soil.]

B. Have students examine Figure 12 on page 46, which shows the areas with a potential for wind erosion. Discuss Questions 1–3.

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Lesson 7

Is conventional farming in the western United States sustainable?

Objectives

In this lesson, you will

- Understand the problems of conventional farming in the western United States.
- Explain why U.S. farmers expanded production onto arid lands.
- Analyze whether sustainable agriculture makes economic sense.

Glossary Words

aquifer, cash crops, fodder, herbicide, legumes, marginal land, monocropping, nonrenewable resource, pesticide, soil, topsoil

What environmental problems does farming cause on arid western lands?

Conventional farming in the United States efficiently produces tremendous quantities of food. Yet some farming systems in the United States create environmental problems. Try to answer the questions on page 46 after you have studied Figure 12.

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Figure 12 U.S. cropland areas with highest potential for soil erosion by wind. Dark areas are most subject to wind erosion.

Source: World Eagle, Inc. 1990

1. In which areas (Figure 12 above) is the potential for soil erosion by wind greatest?
2. What are three reasons why wind can erode soil in these regions?
3. How would extensive farming increase wind-caused erosion?

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Farms in arid and semiarid areas rely on groundwater resources (aquifers) to irrigate the land. The largest of these underground sources is the Ogallala Aquifer on the western Great Plains. Expansion of farming in this area has severely reduced the level of this nonrenewable groundwater resource. In the United States, the groundwater level is falling beneath 40 percent of the irrigated farmland. In some cases, the level is dropping several feet per year (Brown 1987).

Here's a graphic example of what drought can really mean.

When the Soil Blew Away

On a December morning in 1977, Sheriff Larry Kleier drove his patrol car southeast from Bakersfield, California, into the Tehachapi Mountains. It was a cold, clear day, but unusually windy. It was the second year of drought, and the farmlands of the San Joaquin Valley were gray and blistered. . . .

As he drove up a ridge, Kleier saw only blue sky and sunlight over the hood of the car. But when he started down into a valley, everything changed. "Just as I came over the hill," he says, "it was like someone turned off the lights." The wind became extremely violent, and an enormous dust cloud enveloped the car. "I started trying to find a way to go back, but I couldn't stop or turn around. I heard the traffic going by on the other side of the road, but I couldn't see it."

A sudden burst of wind raked the windshield with rocks and gravel, instantly frosting it milky white. Kleier could barely see the end of the hood. . . . "And . . . the rocks started breaking my windows." First the back window shattered. Then the side windows. Dust filled the car. The radio stopped working. It was hard to breathe. . . .

Outside, the dust tore open the countryside. Winds over 100 mph broke wooden telephone poles and buckled steel powerline supports. . . . Cattle suffocated in the dust at fencelines and were found with the hair and skin sandblasted off their hindquarters. The wind sanded two feet off the tops of freshly plowed fields, lofted the soil high into the atmosphere, and carried it hundreds of miles. It came down days later as red rain in [northern California]. . . .

The volume of dust moved by the storm was due much to human activities. Geologists estimate that the winds carried 25 million tons of soil from the foothill areas that the California Department of Conservation had warned were "consistently overgrazed." On the hills, you could look down fencelines and see that heavily grazed lands had lost their topsoil, while on less intensively grazed lands across the fence, both grass and soil were still in place. The geologists estimated that another 25 million tons of soil blew off the freshly plowed fields of the valley. They noted that in recent years the farmers had torn out the windbreaks planted in the 1940s to contain wind erosion (Steinhart 1985, pages 94–95).

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What motivated California ranchers to graze their lands too heavily? Why do you think farmers destroyed the windbreaks that contained wind erosion?

Why are marginal lands in the western United States used for agriculture?

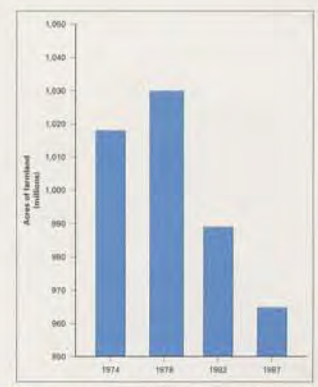

Figure 13 Total acreage of farmland in the United States, 1974–1987

Sources: U.S. Department of Commerce, Bureau of the Census, 1978 Census of Agriculture and 1987 Census of Agriculture

Questions and Answers for page 46

1. In which areas (Figure 12) is the potential for soil erosion by wind greatest?
   - Highest erosion potential is in the Great Plains (West Texas north to the Dakotas and Montana); the Gulf and Atlantic coasts; and scattered areas in the far West. Note that the most extensive area is just west of the 100°W longitude line.

2. What are three reasons why wind can erode soils in these regions?
   - (1) Dry and loose, usually sandy, soil; (2) Little vegetation to hold soil (semiarid climates in most cases); (3) Strong winds (especially on coasts and plains). In sum, areas that are flat, with few trees and surface features to break the wind, have greater air movement at ground level, which can move loose, dry soil.

3. How would extensive farming increase wind-caused erosion?
   - Most wind erosion in the United States is caused by plowing and harvesting methods that leave soil bare and unprotected or by expansion of farming onto drylands that erode easily in wind.

C. Next is a brief discussion of how agriculture in the West can deplete groundwater resources. Ask whether the use of groundwater resources to support irrigated agriculture on drylands appears sustainable. [The answer is no: If aquifer levels are dropping, the resource is being used faster than it can be renewed.]

The reading "When the Soil Blew Away" on page 47 may help dramatize the problem of wind erosion for younger students. Skip this reading if you wish to move on. The closing question about why farmers were motivated to overgraze their lands leads in to the next section.

Why are marginal lands in the western United States used for agriculture? (pages 48–50)

D. Another issue in western U.S. agriculture is the overproduction of food. Here the focus is on economically unsustainable practices, in contrast to the ecological problems just discussed. Have students examine Figure 13 on page 48; ask students to speculate why farm acreage increased in the 1970s but decreased in the 1980s.

Have students read through Table 8 on page 49. The time line describes how economic and political factors have led to overproduction, accounting for the trends shown in Figure 13. Discuss Questions 4–9 (or have students work individually or in groups to answer the questions).

For older students, further investigation on events in the time line can be useful. Interviews with parents concerning the OPEC oil embargo in the 1970s or with each other about the drought of 1988 can be useful. Having them gather any archival material of these two events would be worthwhile.

Questions and Answers for page 50

4. Why did the U.S. government want to pay farmers to grow food during the Depression? Why did these policies encourage monocropping?
   - Government support for farm prices helped ease the hardships caused by the worldwide Depression. Programs favored the cultivation of a few crops. Farmers began growing those grains that had price supports.

5. Why did farmers rely so much on chemical-based fertilizers beginning in 1950?
   - Rising world demand for U.S. food after World War II spurred greater use of fertilizers and also caused expansion onto lands marginally suited for farming. Availability of then-cheap fuel and petroleum-based fertilizers meant that farmers could raise crops on these lands.

6. Why did the acreage under production increase after 1974?
   - When oil prices skyrocketed after 1973 (because of the Organization of Petroleum Exporting Countries [OPEC] oil embargo following the Arab-Israeli War), world markets for U.S. agricultural products increased. Farmers expanded acreage under production (Figure 13).

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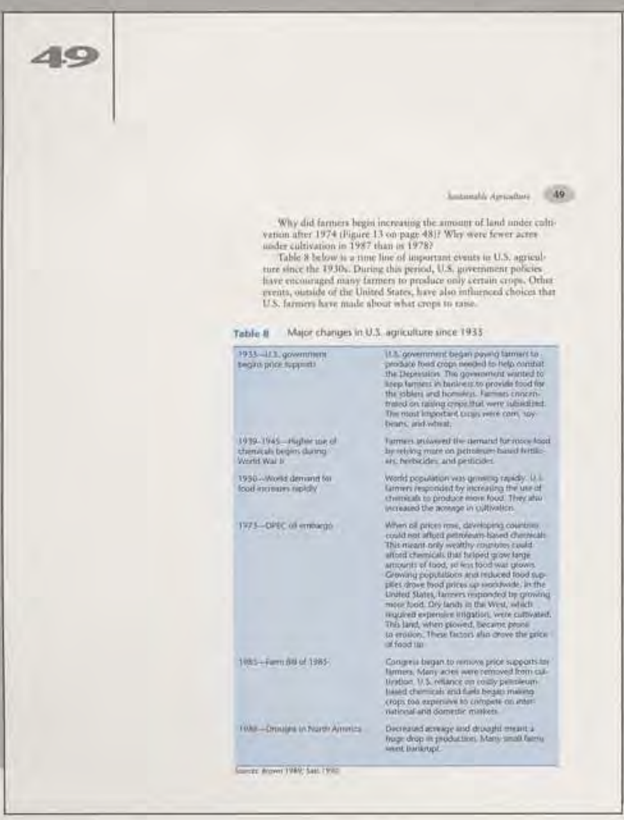
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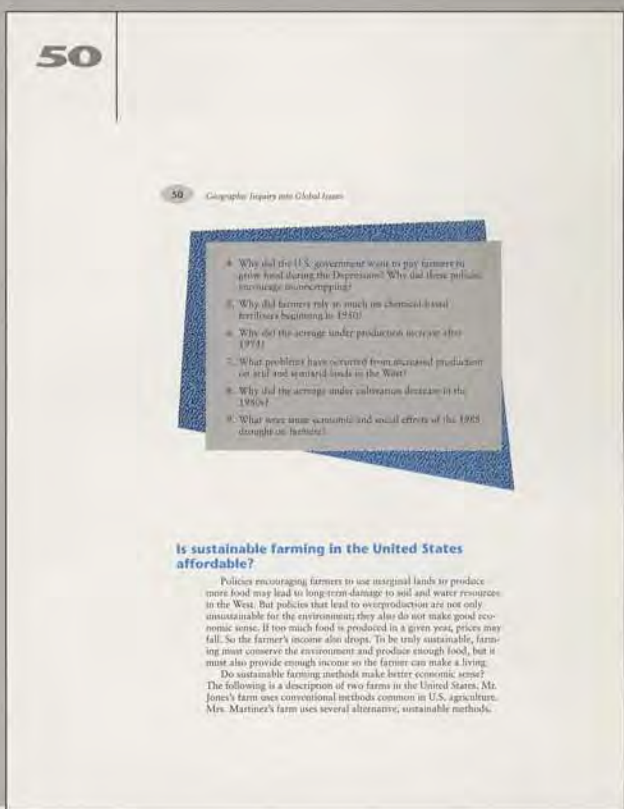
Why did farmers begin increasing the amount of land under cultivation after 1974 (Figure 13 on page 48)? Why were fewer acres under cultivation in 1987 than in 1978?

Table 8 below is a time line of important events in U.S. agriculture since the 1930s. During this period, U.S. government policies have encouraged many farmers to produce only certain crops. Other events, outside of the United States, have also influenced choices that U.S. farmers have made about what crops to raise.

Table 8 Major changes in U.S. agriculture since 1933

1933—U.S. government begins price supports	U.S. government began paying farmers to produce food crops needed to help combat the Depression. The government wanted to keep farmers in business to provide food for the jobless and homeless. Farmers concentrated on raising crops that were subsidized. The most important crops were corn, soybeans, and wheat.
1939–1945—Higher use of chemicals begins during World War II	Farmers answered the demand for more food by relying more on petroleum-based fertilizers, herbicides, and pesticides.
1950—World demand for food increases rapidly	World population was growing rapidly. U.S. farmers responded by increasing the use of chemicals to produce more food. They also increased the acreage in cultivation.
1973—OPEC oil embargo	When oil prices rose, developing countries could not afford petroleum-based chemicals. This meant only wealthy countries could afford chemicals that helped grow large amounts of food, so less food was grown. Growing populations and reduced food supplies drove food prices up worldwide. In the United States, farmers responded by growing more food. Dry lands in the West, which required expensive irrigation, were cultivated. This land, when plowed, became prone to erosion. These factors also drove the price of food up.
1985—Farm Bill of 1985	Congress began to remove price supports for farmers. Many acres were removed from cultivation. U.S. reliance on costly petroleum-based chemicals and fuels began making crops too expensive to compete on international and domestic markets.
1988—Drought in North America	Decreased acreage and drought meant a huge drop in production. Many small farms went bankrupt.

Source: Brown 1989; Sais 1990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4. Why did the U.S. government want to pay farmers to grow food during the Depression? Why did these policies encourage monocropping?
5. Why did farmers rely so much on chemical-based fertilizers beginning in 1950?
6. Why did the acreage under production increase after 1974?
7. What problems have occurred from increased production on arid and semiarid lands in the West?
8. Why did the acreage under cultivation decrease in the 1980s?
9. What were some economic and social effects of the 1988 drought on farmers?

Is sustainable farming in the United States affordable?

Policies encouraging farmers to use marginal lands to produce more food may lead to long-term damage to soil and water resources in the West. But policies that lead to overproduction are not only unsustainable for the environment; they also do not make good economic sense. If too much food is produced in a given year, prices may fall. So the farmer's income also drops. To be truly sustainable, farming must conserve the environment and produce enough food, but it must also provide enough income so the farmer can make a living.

Do sustainable farming methods make better economic sense? The following is a description of two farms in the United States. Mr. Jones's farm uses conventional methods common in U.S. agriculture. Mrs. Martinez's farm uses several alternative, sustainable methods.

7. What problems have occurred from increased production on arid and semiarid lands in the West?
   - In western drylands, this resulted in the cultivation of marginal lands—prone to soil erosion—requiring heavy irrigation, leading to depletion of groundwater resources.

8. Why did the acreage under cultivation decrease in the 1980s?
   - Acreage decreased because of environmental problems but mainly because of the removal of price supports. U.S. farm products were not as competitive on international markets and so production declined and farms went out of business. (The social impacts of this decline in U.S. farming are profound, but somewhat beyond the scope of this module. See *Extension Activities and Resources*.)

9. What were some economic and social effects of the 1988 drought on farmers?
   - Since this event is fairly recent, see if the students remember the drought of 1988. Ask them how the drought of 1988 could have affected agricultural output and world food prices. Some effects included a loss of income for many small farmers. Many people lost their lands and had to leave small rural communities throughout the Great Plains.

Is sustainable farming in the United States affordable? (pages 50–53)

E. At this point, it may help to review some basic ideas, methods, and procedures of sustainable farming. Although sustainable practices must have many local variations, this section deals with general ideas. Brainstorm with the class a list of elements that define agricultural sustainability. [Key points include reliable production of food; conservation of soil and water resources; and ability to provide farmer with sufficient income.]

Have students read about the Jones and Martinez farms on pages 51–52, which are composites of real situations, somewhat exaggerated to draw the distinction between conventional and sustainable methods. Have students complete **Activity 4**. Students could work in pairs on this exercise. See *Key for Activity 4*.

Younger students may enjoy making sketches on butcher paper of the differences between the two farms. They can also cut pictures out of magazines.

F. Table 9 shows that sustainable agriculture can compete on a cost/profit basis with conventional agriculture. Discuss Questions 10–14 (or have the student pairs from Activity 4 answer these questions together).

Younger students may need some help with the concepts of cost, income, and profit. Return to the concepts discussed in Lesson 1 (inputs and outputs of farming). Costs represent the sum of all monetary inputs; income is the monetary return earned from the sale of crops. Profit is the difference between the two.

Questions and Answers for page 53

10–11. What is the difference in profit per acre between the two types of farming? What would the difference in profits be if both farms had 1,500 acres?

- The difference is $8 per acre; sustainable methods are in fact more profitable than conventional methods. Students may appreciate this more by figuring that a farm of 1,500 acres would earn an additional $12,000 annually. To make this question more relevant to your local/regional conditions, substitute the typical size of local farms for the 1,500 acres given.

12. What category is most important in accounting for the difference in net cash profits?

- Students can see that the difference in income ($1/acre) is not meaningful. The area where sustainable methods have a big advantage is in the input costs.

13. Why are costs on a sustainable farm lower than on a conventional farm? (You may want to look back at the descriptions of the Jones and Martinez farms.)

- Sustainable methods (as detailed for the Martinez farm) require fewer chemical fertilizers and pesticides, do not need as much irrigation, and use more fuel-efficient machinery and renewable sources of power.

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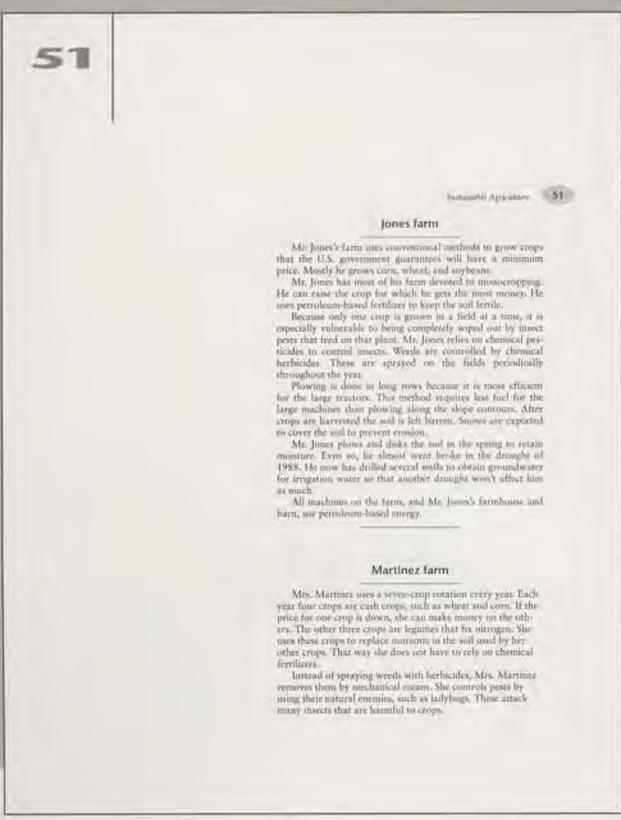

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Jones farm

Mr. Jones's farm uses conventional methods to grow crops that the U.S. government guarantees will have a minimum price. Mostly he grows corn, wheat, and soybeans.

Mr. Jones has most of his farm devoted to monocropping. He can raise the crop for which he gets the most money. He uses petroleum-based fertilizer to keep the soil fertile.

Because only one crop is grown in a field at a time, it is especially vulnerable to being completely wiped out by insect pests that feed on that plant. Mr. Jones relies on chemical pesticides to control insects. Weeds are controlled by chemical herbicides. These are sprayed on the fields periodically throughout the year.

Plowing is done in long rows because it is most efficient for the large tractors. This method requires less fuel for the large machines than plowing along the slope contours. After crops are harvested the soil is left barren. Snows are expected to cover the soil to prevent erosion.

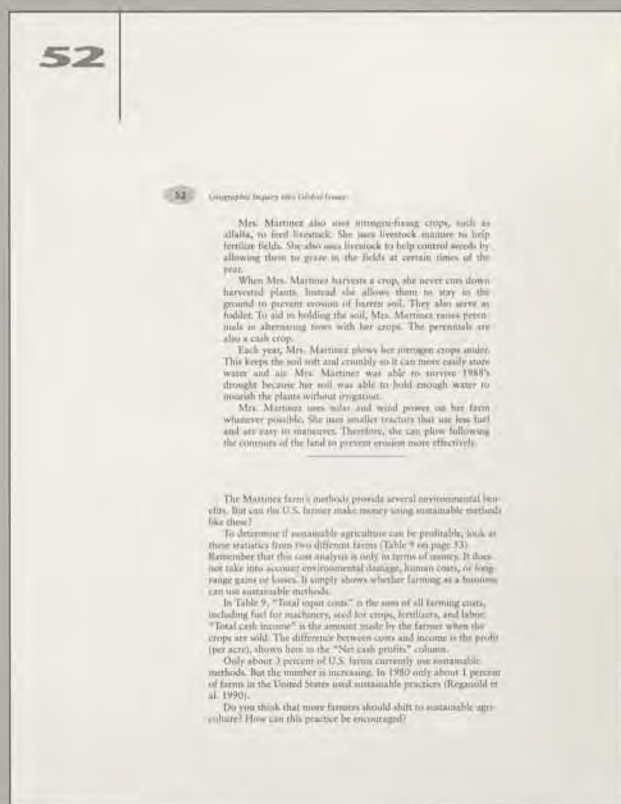
Mr. Jones plows and disks the soil in the spring to retain moisture. Even so, he almost went broke in the drought of 1988. He now has drilled several wells to obtain groundwater for irrigation water so that another drought won't affect him as much.

All machines on the farm, and Mr. Jones's farmhouse and barn, use petroleum-based energy.

Martinez farm

Mrs. Martinez uses a seven-crop rotation every year. Each year four crops are cash crops, such as wheat and corn. If the price for one crop is down, she can make money on the others. The other three crops are legumes that fix nitrogen. She uses these crops to replace nutrients in the soil used by her other crops. That way she does not have to rely on chemical fertilizers.

Instead of spraying weeds with herbicides, Mrs. Martinez removes them by mechanical means. She controls pests by using their natural enemies, such as ladybugs. These attack many insects that are harmful to crops.



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Mrs. Martinez also uses nitrogen-fixing crops, such as alfalfa, to feed livestock. She uses livestock manure to help fertilize fields. She also uses livestock to help control weeds by allowing them to graze in the fields at certain times of the year.

When Mrs. Martinez harvests a crop, she never cuts down harvested plants. Instead she allows them to stay in the ground to prevent erosion of barren soil. They also serve as fodder. To aid in holding the soil, Mrs. Martinez raises perennials in alternating rows with her crops. The perennials are also a cash crop.

Each year, Mrs. Martinez plows her nitrogen crops under. This keeps the soil soft and crumbly so it can more easily store water and air. Mrs. Martinez was able to survive 1988's drought because her soil was able to hold enough water to nourish the plants without irrigation.

Mrs. Martinez uses solar and wind power on her farm whenever possible. She uses smaller tractors that use less fuel and are easy to maneuver. Therefore, she can plow following the contours of the land to prevent erosion more effectively.

The Martinez farm's methods provide several environmental benefits. But can the U.S. farmer make money using sustainable methods like these?

To determine if sustainable agriculture can be profitable, look at these statistics from two different farms (Table 9 on page 53). Remember that this cost analysis is only in terms of money. It does not take into account environmental damage, human costs, or long-range gains or losses. It simply shows whether farming as a business can use sustainable methods.

In Table 9, "Total input costs" is the sum of all farming costs, including fuel for machinery, seed for crops, fertilizers, and labor. "Total cash income" is the amount made by the farmer when the crops are sold. The difference between costs and income is the profit (per acre), shown here in the "Net cash profits" column.

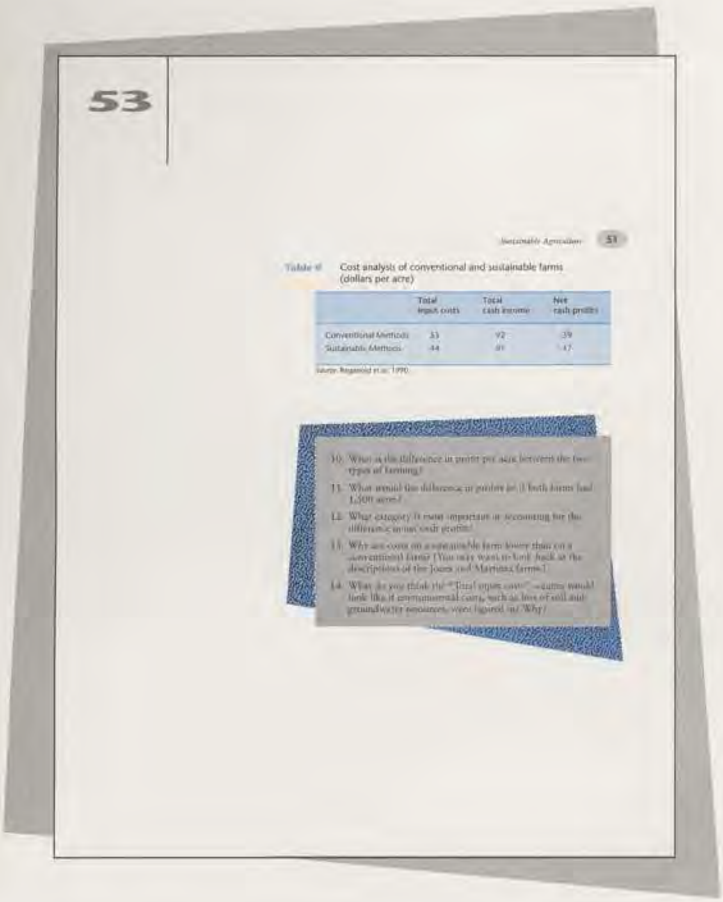
Only about 3 percent of U.S. farms currently use sustainable methods. But the number is increasing. In 1980 only about 1 percent of farms in the United States used sustainable practices (Reganold et al. 1990).

Do you think that more farmers should shift to sustainable agriculture? How can this practice be encouraged?

14. What do you think the "Total input costs" column would look like if environmental costs, such as loss of soil and groundwater resources, were figured in? Why?

    - Presumably the difference in costs would be even more favorable for sustainable methods. This is a key point, because if cost-benefit analyses fail to account for environmental pollution, they can underestimate the "true" cost.

G. Close the lesson by posing the closing questions on page 52. Also ask students: *If sustainable agriculture is so productive, why don't more farmers switch*? This point was made in this Teacher's Guide at the end of Lesson 6, Procedure D. The key is that such conversions can be difficult and costly for individual farmers. Discuss with students how government policies favoring conventional methods may discourage farmers from using more sustainable methods. Emphasize how outside factors often control farmers' decisions. Have students come up with ideas for disseminating knowledge about sustainable methods (e.g., supporting training in new methods for farmers; having university and agricultural extension agents act as promoters of sustainable techniques, etc.).



For Further Inquiry

- Assign an essay in which students explain how conventional farming in the West has led to depletion of soil and water resources.
- Using the time line (Table 8), pose a problem from each date given and have students describe how the policy or event contributed to overproduction.

Lesson 8

How can world agriculture be made sustainable?

Time Required

One 50-minute class period

Materials Needed

Transparency of Overhead 2

Glossary Words

marginal land

soil

Procedures

A. Have students read the list of 10 agricultural problems on pages 54–55. This is a partial list; you can have students recall other problems discussed in the module. The text goes on to define the general problems facing more-developed and less-developed countries. Be sure students understand what is meant by these terms. Ask students to provide examples of each type of country, and list these on the board. Make sure the United States and Malaysia are mentioned. (It may help to review Table 3 on page 25, showing the differences in per capita income between these two nations.)

B. Divide the class into groups of three or four students each. Challenge each group to devise some solutions to some or all of the problems. The length of this activity is up to you. If there is great interest, groups could be encouraged to go to the library to gather more information on the strategies proposed to solve agricultural problems. Several days could be spent on this inquiry.

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54 Geographic Inquiry into Global Issues

Lesson 8

How can world agriculture be made sustainable?

Objective

In this lesson, you will:

- Develop a strategy for promoting sustainable agriculture around the world.

Glossary Words

marginal land

soil

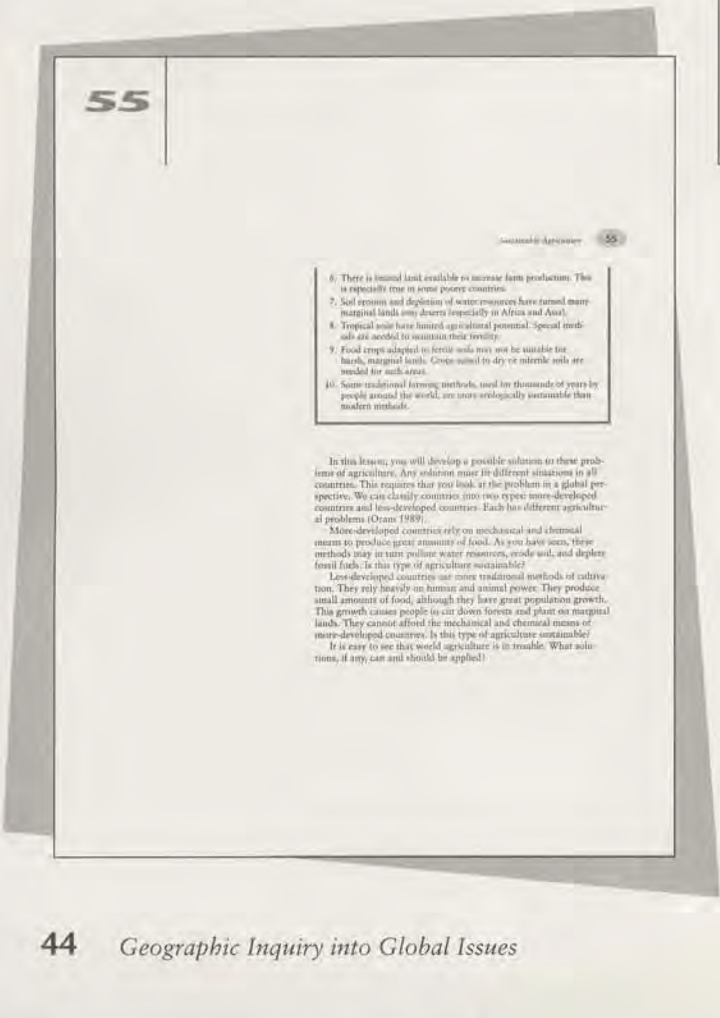
A review: 10 problems with world agriculture

1. To feed the world's growing population, more food is needed.
2. Agricultural productivity has increased tremendously in the last 40 years. Most of this increase is from heavy use of petroleum-based fertilizers.
3. The countries where most of the world's people live are growing the fastest, but they are usually too poor to afford petroleum-based fertilizers.
4. Food productivity in industrial countries is already near the biological maximum—that is, as much as the plants themselves can produce.
5. Mechanization of farms has reduced the need for farm labor. Many farmers have migrated to cities, increasing urban growth.

Alternatively, you can wrap up the module in one day by presenting the information on **Overhead 2** and simply having students evaluate how this plan addresses the key issues raised in the module. This plan is the framework for sustainability used by the Food and Agriculture Organization of the United Nations. It is necessarily basic. Have students explain how these strategies relate to sustainability. Discussion on some of the points of this plan might proceed as suggested *in the Suggestions for Using Overhead 2.*

For Further Inquiry

For an authentic assessment, it may be interesting to have students design a farm that is sustainable. Using all information in the module would give enough background for them to create a reasonable model. Using some clean junk or garbage (which they can bring in or you can gather), have them create three-dimensional models of sustainable farms. The materials are not that important, but creating a model would be a good, hands-on evaluation.



55

Sustainable Agriculture 55

6. There is limited land available to increase farm production. This is especially true in some poorer countries.
7. Soil erosion and depletion of water resources have turned many marginal lands into deserts (especially in Africa and Asia).
8. Tropical soils have limited agricultural potential. Special methods are needed to maintain their fertility.
9. Food crops adapted to fertile soils may not be suitable for harsh, marginal lands. Crops suited to dry or infertile soils are needed for such areas.
10. Some traditional farming methods, used for thousands of years by people around the world, are more ecologically sustainable than modern methods.

In this lesson, you will develop a possible solution to these problems of agriculture. Any solution must fit different situations in all countries. This requires that you look at the problem in a global perspective. We can classify countries into two types: more-developed countries and less-developed countries. Each has different agricultural problems (Orans 1989).

More-developed countries rely on mechanical and chemical means to produce great amounts of food. As you have seen, these methods may in turn pollute water resources, erode soil, and deplete fossil fuels. Is this type of agriculture sustainable?

Less-developed countries use more traditional methods of cultivation. They rely heavily on human and animal power. They produce small amounts of food, although they have great population growth. This growth causes people to cut down forests and plant on marginal lands. They cannot afford the mechanical and chemical means of more-developed countries. Is this type of agriculture sustainable?

It is easy to see that world agriculture is in trouble. What solutions, if any, can and should be applied?

Suggestions for Using Overhead 2 (numbers refer to the 10 points of the AEZ Project)

1. Ask what determines suitability of a crop (e.g., its ability to grow in the local soil type). Ask what crops might be suitably grown in the United States? In Malaysia?
2. How might crops grown in Malaysia be affected by other areas? The development of artificial rubber or the decline in use of tropical oils demonstrate the interdependence between places.
3. Use the western United States as an example of how land might not be wisely used.
5. Use the Cameroon case as an example of how livestock might be wisely used.
7. Ask why it would be important to develop plant breeds that are resistant to drought and disease. These would cut down on irrigation needs and the need for chemical pesticides.
8. The differences between East and West Malaysia provide a good example for this point. Different cultures have different agricultural needs: Shifting cultivators on East Malaysia have different problems than commercial growers on the Malay Peninsula.
10. For good ideas to spread, it is important that they be shared.

1 2 3 4 5 CP 99 98 97 96 95

Extension Activities and Resources

1. **Related GIGI Modules**
   - The history of Malaysia is interesting, and students could pursue independent library work to learn more about the country. Prior to independence, these lands had to struggle with colonial policies; since independence, Malaysia has had both international conflicts with Indonesia and internal conflicts among its numerous ethnic groups. In addition, Malaysia has had to establish policies to deal with refugees from Vietnam and Cambodia. Other GIGI modules that address these issues include *Building New Nations, Diversity and Nationalism,* and *Human Rights.* Although these modules do not include coverage of Malaysia, students could supplement the materials with their own investigations about Malaysia.
   - The module *Global Economy* explores how Japanese economic interests and decisions affect the environmental quality of other places. One lesson in the module looks in-depth at the issue of deforestation in Sabah and Sarawak, which is attributed to the practices of Japanese timber companies and the policies of the East Malaysian government. The lesson also explores how forest-clearance programs are affecting traditional cultures in East Malaysia.

2. **Britannica Global Geography System (BGGS)**

   BGGS provides myriad extension activities to enhance each GIGI module. For a complete description of the BGGS CD-ROM and videodiscs and how they work with the GIGI print modules, please read the BGGS Overview in the tabbed section at the beginning of this Teacher's Guide.

3. **Related Videos**
   - EBEC videos "Soil: A Natural Habitat" and "Soil: Preserving a Natural Resource" explore the issues studied in this module.
   - Other related videos include: "Feast or Famine?" (*Spaceship Earth,* PBS); "Down on the Farm" *(Nova* series, PBS); and "Fueling the Future" (PBS).

4. **Additional Activities**

- The issue of using petroleum for increasing agricultural production opens up interesting debate possibilities. Because petroleum is nonrenewable, what should it be used for? Some might argue that feeding the world's people is more important than feeding automobiles. Others could take the position that, because petroleum is so valuable and necessary for human survival, it is worth extracting oil wherever it is found, including wilderness or coastal areas. This is of course a hot topic in some areas, but it lies somewhat beyond the scope of this module.

- Students could use the library to investigate traditional systems of agriculture in different parts of the world to see how different cultures adapted their farming methods to match local conditions. A study of Native American agricultural practices might be especially interesting. Analysis could focus on what elements of the traditional systems were sustainable.

- Have students investigate the social impacts of farm failures in the United States. Issues include the decline of small, family farms in the United States, the disintegration of rural communities, migration to cities, and so on. History and English classes might use John Steinbeck's classic about Depression-era farm migrants, *The Grapes of Wrath,* as background for this investigation.

- For older students, a challenging extension would be to have them define the general elements of sustainable resource management. Four elements that have been defined as *sustainability* in general are (a) opportunities for economic development for all; (b) equity of opportunity for all groups in society; (c) equity for opportunity for all generations, present and future; and (d) maintaining the integrity and stability of the global ecosystem.

5. **Writing**

- For information on what is being done to make sustainable agriculture happen, have students write to the Land Institute in Salina, Kansas. This ongoing research project, founded by Wes Jackson, is the recognized center of sustainable agriculture in the United States (See the Eisenberg article in *The Atlantic Monthly* listed in the References section for more on Jackson and the Land Institute.) Older students who are genuinely interested in the issue may wish to consider applying for internships at the Institute during their college years. Address:

  The Land Institute
  2440 E. Water Well Road
  Salina, KS 67401

- Have students imagine that they have been invited to give a presentation of farming at a world conference on the future. Have them write and present a short paper that describes and explains why they believe that sustainable agriculture is important for the future of human life on Earth.

6. Outside Experts

- Invite speakers from the Peace Corps or from other organizations that deal with sustainability in some form. It would give students a chance to voice their own ideas and hear the real-world problems of sustainable agriculture.

✎Names ________________________

____

Agricultural Inputs and Outputs

Directions: Arrange the 18 terms below into two lists. One list will be agricultural inputs and the other list will be agricultural outputs. Inputs are actions, tools, or products used by the farmer to grow crop plants. Outputs are the results of farming, both intended and unintended.

Terms

plowing the soil
release of chemicals into streams
chemical pesticides
natural fertilizers (manure)
crops for sale
fuel for farm machinery
depletion of petroleum resources
crops to feed family
obtain groundwater in wells
crops to feed livestock
reduction of soil fertility
chemical fertilizers
groundwater contamination
farm machinery
chemical weed killers
irrigation
release of air pollutants
soil erosion

Inputs	Outputs

After you have classified the terms, put a star next to the outputs that harm the environment. Which of these harm water resources? Which harm the soil resource? Which are related to fossil fuel resources? Can you identify which inputs lead to these harmful outputs?

Agricultural Inputs and Outputs

Inputs	Outputs
plowing the soil	*release of chemicals into streams
chemical pesticides	crops for sale
natural fertilizers (manure)	*depletion of petroleum resources
fuel for farm machinery	crops to feed family
obtain groundwater in wells	crops to feed livestock
chemical fertilizers	*reduction of soil fertility
farm machinery	*groundwater contamination
chemical weed killers	*release of air pollutants
irrigation	*soil erosion

- Effects involving water include release of chemicals into streams and groundwater contamination.
- Effects involving soil include reduction of soil fertility and soil erosion.
- Effects involving fossil fuels include depletion of petroleum resources and release of air pollutants.

Relationships Between Inputs and Outputs

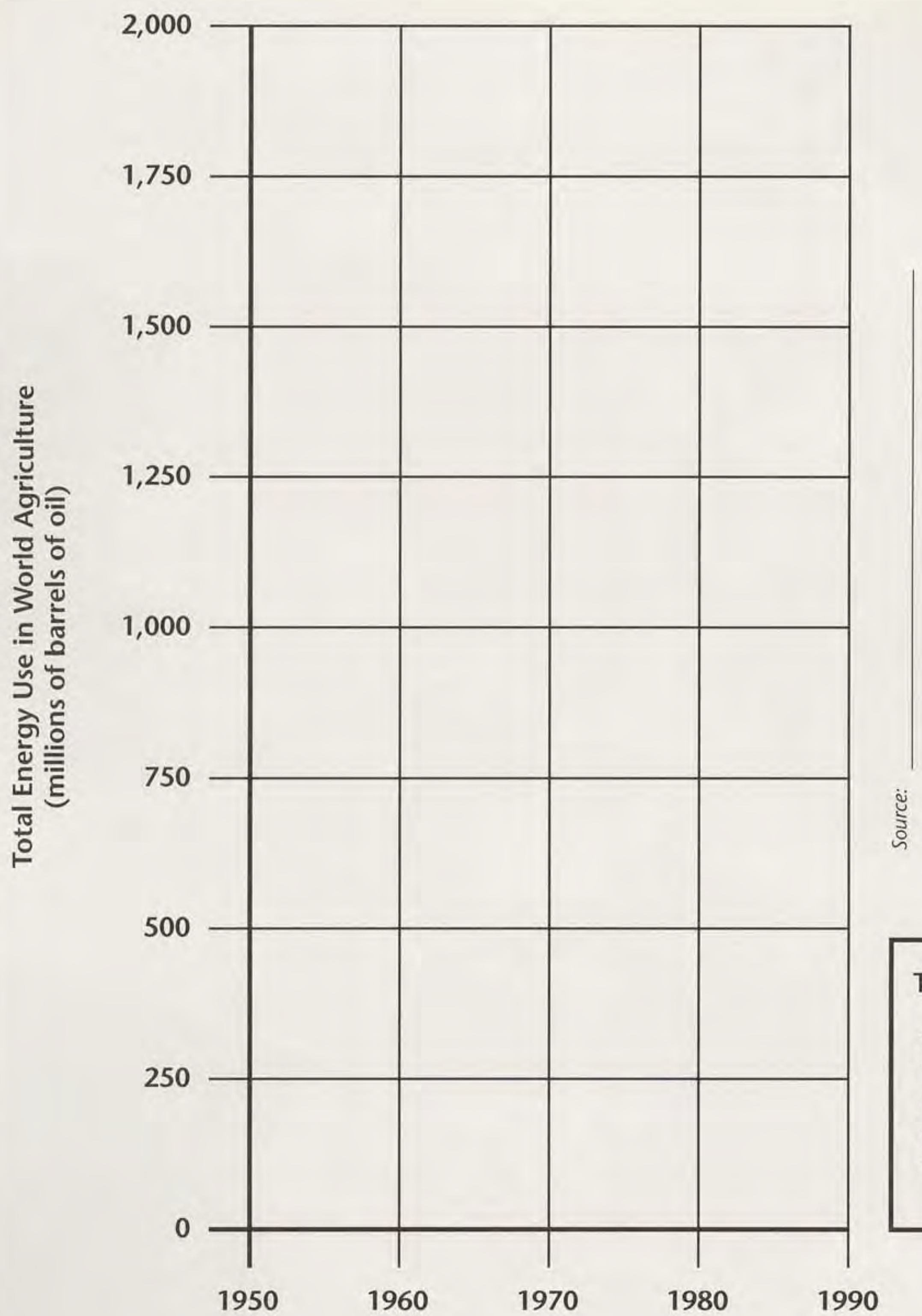
Water: Chemical fertilizers, herbicides, and pesticides, once used, can run off into surface waters (streams) or infiltrate through the soil into subsurface water (groundwater).

Soil: Plowing brings loose soil to the surface, leaving the soil vulnerable to erosion by wind and water. Soil fertility is reduced over time by the very fact that crop plants require nutrients. Fertilizers (natural and chemical) are needed to replace lost nutrients.

Fossil fuels: Machinery requires oil and gas; over time this usage contributes to the general depletion of petroleum resources and emission of air pollutants. Also, chemical fertilizers, herbicides, and pesticides are usually synthesized from oil.

Important: Not all of these relationships will be apparent at this stage of the module. Use this information only to clarify student questions; part of the purpose here is to stimulate interest in the issue by generating these questions. Most of these relationships are discussed and explained in Lesson 2.

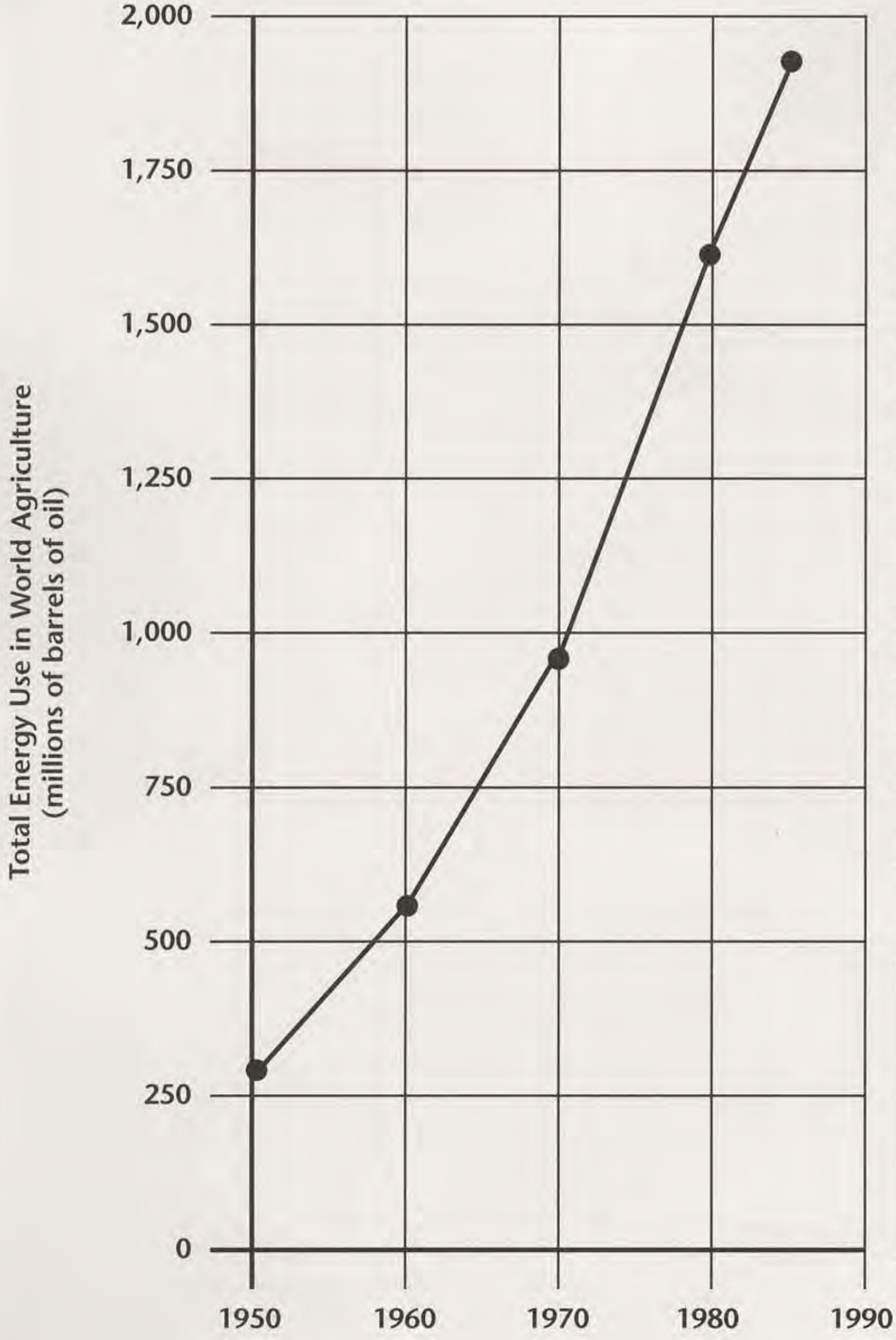
Total Energy Use in World Agriculture, 1950–1990



Total Energy Use

1950 ________
1960 ________
1970 ________
1980 ________
1985 ________

Total Energy Use in World Agriculture, 1950–1990



Source: Brown, L. R. 1987. "Sustaining World Agriculture." In L. R. Brown, ed., *State of the World—1987*. New York: Norton/Worldwatch.

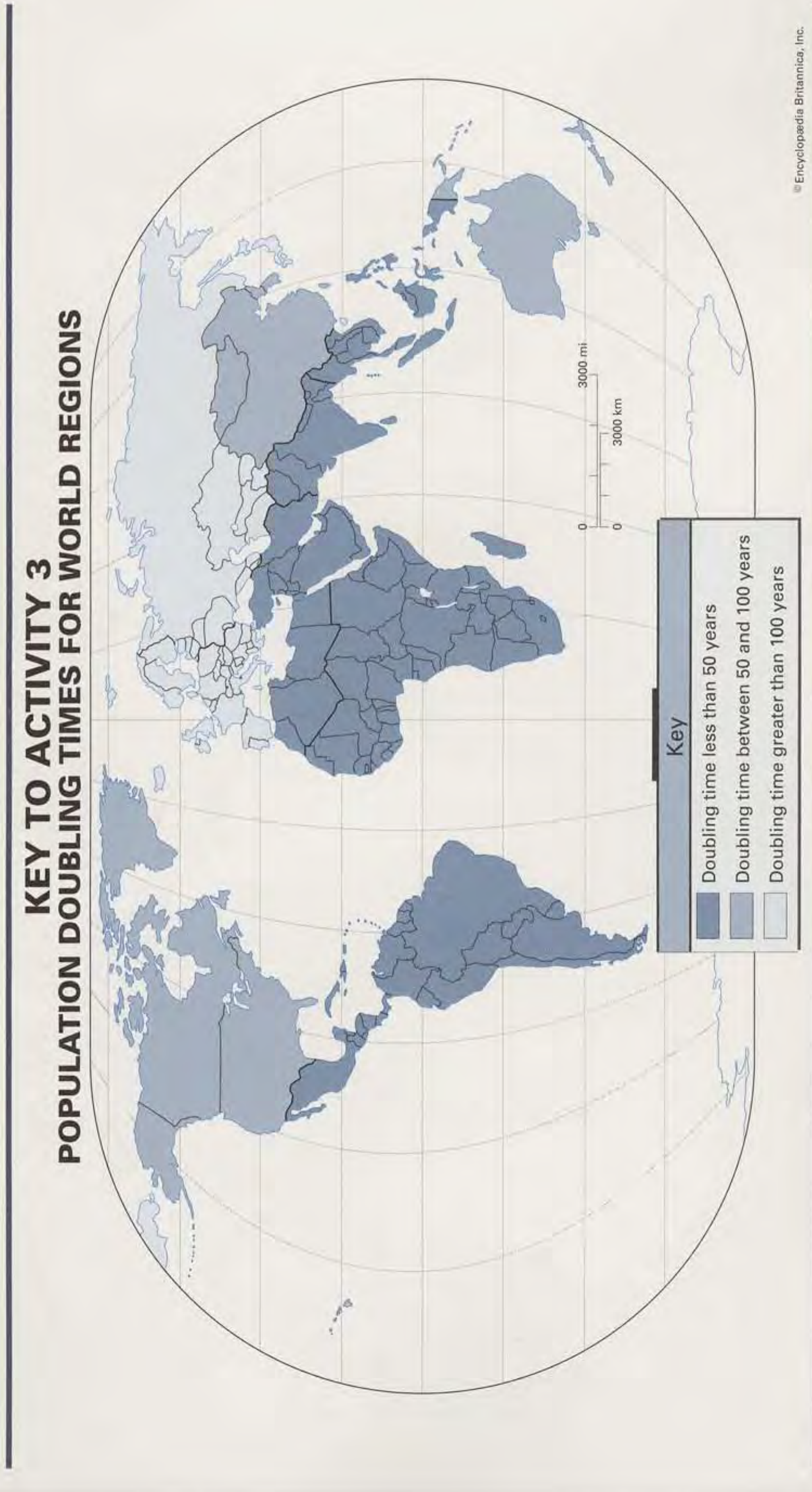
Total Energy Use

1950	276
1960	545
1970	970
1980	1,609
1985	1,903

✎Name ______________________

Population Doubling Times for World Regions

Population Doubling Times for World Regions



✎Names ____________________

____

Sustainable and Conventional Farms

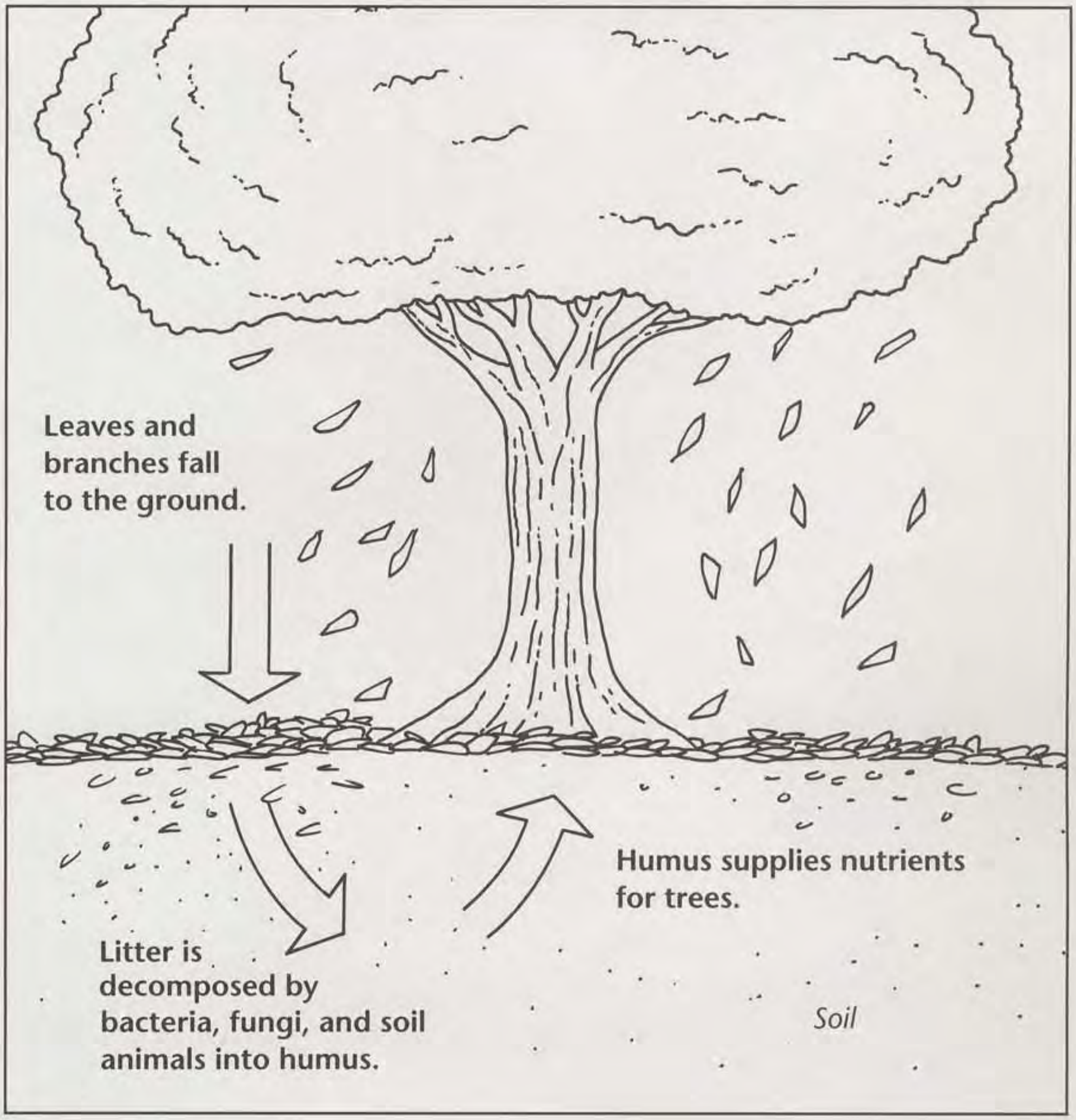
Directions: After reading about the Jones and Martinez farms, fill out the following chart based on the farming practices of the two.

	Jones	**Martinez**
Crop		
Crop rotation		
Plowing/harvesting methods		
Erosion prevention		
Herbicides		
Insecticides		
Fertilizers		
Energy sources		
Water sources		

Sustainable and Conventional Farms

	Jones	Martinez
Crop	Corn, wheat, soybeans	Many crops
Crop rotation	None (monocropping)	Seven crop rotation
Plowing/harvesting methods	Long rows of plowing, barren fields after harvest	Efficient plowing to prevent erosion, crops left in fields after harvest to prevent erosion
Erosion prevention	None	Same as "Plowing/harvesting methods" above. Also, perennials planted in alternating rows
Herbicides	Petroleum/chemical based	None; weeds removed by mechanical means
Insecticides	Petroleum/chemical based	None. Natural enemies of pests used such as ladybugs
Fertilizers	Petroleum/chemical based	Crops high in nitrogen grown and later plowed under
Energy sources	Electric and petroleum based	Solar and wind whenever possible, electric and petroleum otherwise
Water sources	Precipitation, surface water, groundwater	Same as "Energy sources" above. Also, plowing under of nitrogen fixing crops helps soil retain moisture

Nutrient Cycling in the Forest



The AEZ Project

The United Nations Food and Agriculture Organization (FAO) has a framework for sustainable agriculture. The Agroecological Zones (AEZ) Project divides the world into many zones and identifies sustainable crops for each. It looks at many factors related to agriculture in each area when recommending specific crops (Oram 1988). Each zone is examined to:

1. **Find suitable crops for each area.**
2. **Determine how agriculture in one area will affect other areas.**
3. **Identify how the land should not be used.**
4. **Evaluate the agricultural performance of each area.**
5. **Decide how livestock should be raised.**
6. **Determine which crops for any area can withstand any climate changes.**
7. **Collect data relating to new hybrids of plants that might be more resistant to drought, pests, and disease.**
8. **Examine the countries' social, economic, and political backgrounds in helping their agricultural growth.**
9. **Determine what crops grow best in areas known for specific diseases, pests, or weeds. This leads to a reduction in the use of pesticides and herbicides.**
10. **Share and distribute information and data among all countries.**

BRITANNICA GLOBAL GEOGRAPHY SYSTEM

GIGI

Geographic Inquiry into Global Issues

Sustainable Agriculture

Program Developers
A. David Hill, James M. Dunn, and Phil Klein

Regional Case Study
Southeast Asia

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EDUCATIONAL CORPORATION
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Contents

GIGI National Field Trial Locations

Anchorage, AK
Juneau, AK
Birmingham, AL
Grove Hill, AL
Ventura, CA
Arvada, CO
Boulder, CO
Colorado Springs, CO
Lakewood, CO
Westminster, CO
Wilmington, DE
Nokomis, FL
Lithonia, GA
Marietta, GA
Beckemeyer, IL
Red Bud, IL
Lafayette, IN
La Porte, IN
Merrillville, IN
Mishawaka, IN
Eldorado, KS
Morgantown, KY
Lowell, MA
South Hamilton, MA
Westborough, MA
Annapolis, MD
Baltimore, MD
Pasadena, MD
Detroit, MI
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Rochester Hills, MI
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Jefferson City, MO
Raymondville, MO
St. Louis, MO
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Oxford, NE
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Lakewood, NJ
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Pleasant Grove, UT
Salt Lake City, UT
Monroe, WI
Racine, WI
Cheyenne, WY
Worland, WY

Memo to the Student from the GIGI Staff

GIGI stands for *Geographic Inquiry into Global Issues,* which is the name of a series of modules. Each module inquires into a different world issue. We wrote this memo to explain that GIGI is different from most textbooks you have used.

With GIGI, you can have fun learning if you think like a scientist or detective. The main business of both scientists and detectives is puzzle-solving. They use information ("data" to the scientist and "evidence" to the detective) to test their solutions to puzzles. This is what you do with GIGI. GIGI poses many puzzles about important global issues: Each module centers around a major question, each lesson title is a question, and there are many other questions within each lesson. GIGI gives you real data about the world to use in solving these puzzles.

To enjoy and learn from GIGI, you have to take chances by posing questions and answers. Just as scientists and detectives cannot always be sure they have the right answers, you will sometimes be uncertain with GIGI. But that's OK! What's important is that you try hard to come up with answers, even when you're not sure. Many of GIGI's questions don't have clear-cut, correct answers. Instead, they ask for your interpretations or opinions. (Scientists and detectives are expected to do this, too.) You also need to ask your own questions. If you ask a good question in class, that can sometimes be more helpful to you and your classmates than giving an answer.

The data you will examine come in many forms: maps, graphs, tables, photos, cartoons, and written text (including quotations). Many of these come from other sources. Unlike most textbooks, but typical of articles in scientific journals, GIGI gives its sources of data with in-text references and full reference lists. Where an idea or piece of information appears in GIGI, its author and year of publication are given in parentheses, for example: (Gregory 1990). If the material used is quoted directly, page numbers are also included, for example: (Gregory 1990, pages 3–5). At the end of the module you'll find a list of references, alphabetized by authors' last names, with complete publication information for the sources used.

To help you understand the problems, GIGI uses "case studies." These are examples of the global issue that are found in real places. "Major case studies" detail the issue in a selected world region. You will also find one or two shorter case studies that show variations of the issue in other regions.

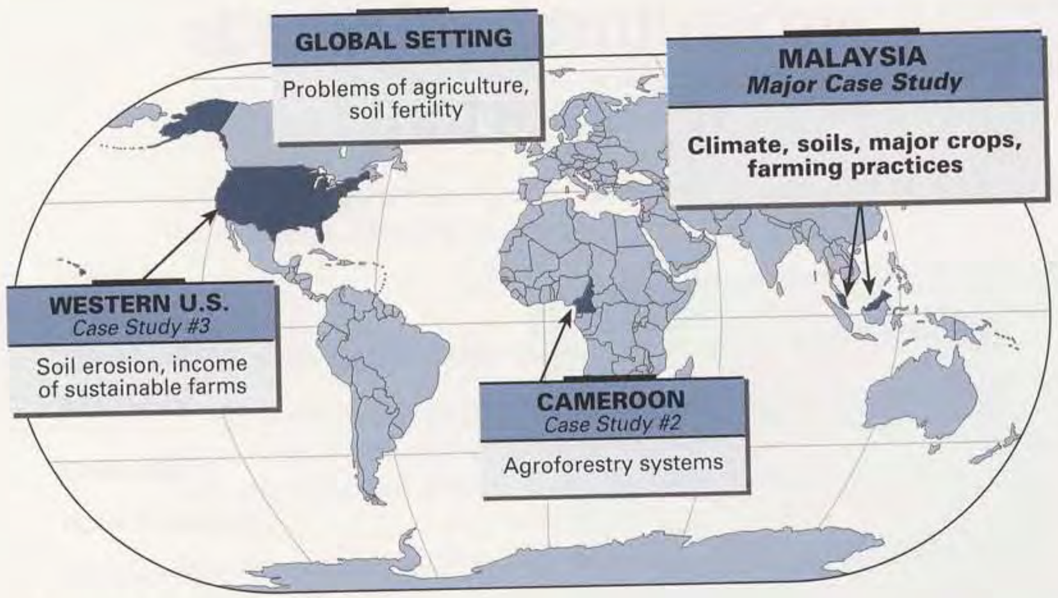
We hope your geographic inquiries are fun and worthwhile!

Sustainable Agriculture

How can the world achieve sustainable agriculture?

- What does *sustainable agriculture* mean?
- How does farming cause environmental problems?
- How can we conserve soil and water resources for future generations?
- Are farmers and gardeners in your area using sustainable methods? If not, why not?

Can the world's growing population be fed if farming methods ruin soil and water resources? In the long run, no. Agriculture must be *sustainable,* which means farming that does not damage the environment *and* produces enough food to feed all people. In this module, you will explore how this can be achieved. The major case study is about Malaysia, whose farming problems are typical of tropical countries. You will also study two other places: another tropical country (Cameroon) and the western United States. You will examine farming practices in these places and decide whether they are sustainable or not.



Questions You Will Consider in This Module

- How does sustainable agriculture differ from conventional farming practices?
- Why is sustainable agriculture necessary for the future of human life?
- Why are tropical soils less fertile than soils in the midlatitudes?
- What kinds of farming practices can maintain soil fertility in the tropics?
- How do politics, economics, and culture influence decisions about agriculture?

Lesson 1

What is sustainable agriculture and why is it important?

Objectives

In this lesson, you will

- Distinguish *sustainable* from *conventional* agriculture.
- Recognize the importance of sustainable agriculture.

Glossary Words

arable land
domestication
ecosystem
fodder
marginal land
monocropping
pesticide
soil

How does agriculture change the environment?

After thousands of years of dependence on wild plants and animals, some human societies gradually learned to domesticate animals and plants. People could then raise their own food, instead of hunting animals and gathering wild plants. This change, which occurred about 10,000 years ago, has been called the "agricultural revolution." Clearly, life as we know it today would be impossible without agriculture. But modern agriculture also creates some environmental problems. Wes Jackson, a prominent U.S. agricultural scientist, has made the following statement:

> So destructive has the agricultural revolution been that, environmentally speaking, it surely stands as the most significant and explosive event to appear on the face of the earth, changing the earth even faster than did the origin of life (Jackson 1980, page 2).

Why did Jackson call agriculture "destructive"? To understand this, it is necessary to recognize how agriculture changes the physical environment.

> Agriculture involves a massive disruption of natural ecosystems, which are cleared to provide fields for growing crops and for grazing domesticated animals. Nutrient recycling is disrupted and extra inputs in one form or another are required to sustain the system (Ponting 1990, page 6).

What "inputs" are needed to sustain an agricultural system? How does modern farming work?

What is sustainable agriculture?

As early as the year 2010, the world's population is expected to grow from its present 5.4 billion to just over 7.1 billion (Population Reference Bureau 1992). This represents a lot of mouths to feed. Production of food will have to increase by more than 50 percent from its present level to feed future populations. Yet most of the world's arable land is already being farmed. Because little new farmland is available, the needed increase in food production must come from better agricultural practices (Wolf 1987).

Throughout history, farmers have improved their techniques to produce more food. Modern farming practices, however, are causing some problems:

> New technologies and scientific methods were developed to help farmers meet the growing demands of expanding urban populations. By substituting mechanical power for horses, for example, farmers could increase their grain acreage by from 20 to 30 percent, because they could plow more ground in less time and did not need to grow fodder. . . .
>
> Nevertheless, by the 1950s technological advances had . . . [created] a system that relied on agrichemicals, new varieties of crops, and labor-saving, energy-intensive farm machinery. This system has come to be known as conventional farming.
>
> As pesticides, inexpensive fertilizers, and high-yielding varieties of crops were introduced, it became possible to grow a crop on the same field year after year—a practice called monocropping. . . . Farmers began to concentrate their efforts on fewer crops. Government programs promoted monoculture by subsidizing only the production of wheat, corn, and a few other major grains.

Unfortunately, these practices set the stage for extensive soil erosion and for pollution of water by agrichemicals (Reganold et al. 1990, page 114).

In contrast to conventional farming, sustainable farming uses methods that, over time, do not reduce the environment's ability to produce food. It is the practice of raising crops and livestock in ways that recognize how the local ecosystem works.

For agriculture to be sustainable, it has to do two things. It must conserve the resources of the physical environment and, at the same time, produce enough food to meet people's needs (Altieri 1987).

Why study sustainable agriculture? Why should you be aware of this even if you're not a farmer? Why is it important for people to practice farming that does not cause long-term harm to the environment?

What can happen if sustainable agriculture is not practiced?

History has many examples of ancient civilizations that collapsed. In two famous cases, the collapse can be blamed partly on unsustainable agriculture.

Ancient Sumer (located in what is now Iraq) was the site of the world's first great civilization, more than 5,000 years ago. Archaeologists have shown that the Sumerian civilization's collapse was caused in part by failed irrigation practices. Using the waters of the Tigris and Euphrates rivers, the Sumerians irrigated large areas of

Ruins of the highly developed ancient Mayan civilization.

land to increase crop production. But because of the region's warm, dry climate, much of this irrigation water evaporated. When water evaporates, the minerals dissolved in it come out of solution, into solid form. Over a period of hundreds of years, this caused a huge amount of salt to build up on the Sumerian soil surface. These salts poisoned the crops and reduced the soil's productivity. At the same time, deforestation in the highlands triggered a great deal of soil erosion. In time, the Sumerians could not grow enough wheat or barley to supply their people. The inability to produce adequate food supplies weakened the society and contributed to its eventual collapse (Ponting 1990).

The Maya developed an advanced civilization in the tropical forests of what is now southern Mexico, Guatemala, and Belize. The Mayan civilization reached its greatest height from about A.D. 600 to 800, but then it disintegrated. To support their population, the Maya cleared forests and planted fields. Crops such as maize (corn) and beans were grown. But as population increased and cultivation intensified, the region's soils—which were not very fertile to begin with—lost their ability to sustain this type of farming. Pressure from growing populations pushed farmers onto increasingly marginal lands. Across the Mayan territories, soils were eroded by wind and rain. When not enough productive new land could be found, the population could not be fed. Within a few decades, the Mayan civilization collapsed (Ponting 1990).

Lesson 2

What environmental problems does conventional farming cause?

Objectives

In this lesson, you will

- Give examples of renewable and nonrenewable resources.
- Explain three environmental problems caused by conventional farming.

Glossary Words

aquifer
hectare
nonrenewable resource
pesticide
renewable resource
soil
topsoil

Why is conventional farming *not* sustainable?

To put this question in context, we must define two terms: renewable resources and nonrenewable resources.

A renewable resource is one that cannot be used up because it is regularly replenished. This means that it can be renewed by natural processes. The important point is that the rate of resource use is slower than the rate of renewal.

Nonrenewable resources, on the other hand, are those that cannot be replaced by natural processes because the rate of resource use is faster than the natural rate of renewal (Miller 1986).

1. What are some examples of renewable resources? Of nonrenewable resources?
2. Would sustainable agriculture use resources faster or slower than they could be renewed? Explain your answer.

The following excerpt from a magazine article summarizes some of the problems with conventional farming, as it has been practiced in the United States during the twentieth century. As you read, consider these questions: *Are these conventional agricultural practices treating resources as renewable or nonrenewable? How do you know?*

> A third of [U.S.] farmland topsoil, accumulated over millennia, [has been lost in the last century]. For every bushel of corn that Iowa grows, it sheds at least two bushels of soil. Farm runoff is . . . poisoning our drinking water. . . . In 1948, at the dawn of the chemical age, American farmers used 15 million pounds of insecticides and lost 7 percent of their crops to insects; today they use 125 million pounds and lose 13 percent. Because most agricultural chemicals are made from fossil fuels, we [use] three calories of energy to produce each calorie of food we eat. . . . In contrast, Tsembaga farmers in highland New Guinea, using Neolithic slash-and-burn methods, [use] less than a tenth of a calorie for each calorie they eat. For each American man, woman, and child, our agriculture [uses] 160 pounds of nitrogen, phosphate, and potash fertilizer each year, and 325 gallons of water each *day.* The Ogallala aquifer of the Great Plains held enough water forty years ago to fill Lake Huron; in another twenty years it may be too low to pump. The great dams of the West are silting up. Sloppy irrigation and poor drainage . . . have caused [salty] conditions on 10 percent of our crop and pasture land. Should we escape the fate of the ancient empires that were done in by erosion, we may instead face that of the Sumerians, whose civilization crumbled as their soil turned salty (Eisenberg 1989, page 59).

A useful way to think of nonrenewable resources is to think about mining. Gold, silver, tin, and all metals mined from Earth are nonrenewable resources. Metal ores were formed by geological processes that happened over millions of years. Such processes cannot renew these ores for many more millions of years. So, every metal mined from Earth is, for society's purposes, irreplaceable.

Conventional farming is, in essence, "mining" three critical resources: fossil fuel, water, and the soil itself (Brown 1987). Let's look at each of these.

"Mining" fossil fuels

Since World War II, farmers have more than doubled the total production of grain crops. These major grain crops include wheat, rice, corn, oats, and barley. Two-thirds of the world's croplands are planted in cereal grains (Brown 1987). Yet now there is actually *less* cropland devoted to grains than there was in 1950 (Figure 1 below). How did farmers do this? How could farmers increase crop production while they used less land? One answer is provided by Table 1 on page 11, which shows the trend in world fertilizer use since World War II.

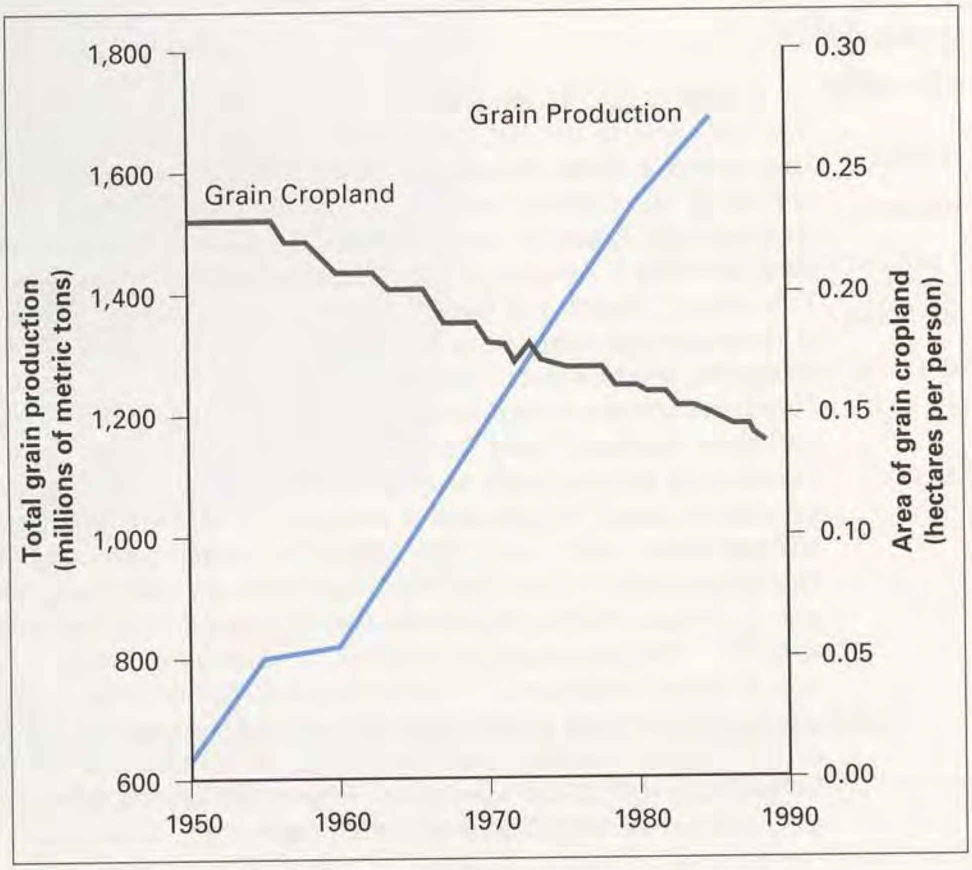


Figure 1 World grain production and area of grain cropland since 1950.

Sources: Brown 1987; 1989.

Table 1 World fertilizer use, 1950–1985

Year	Millions of metric tons
1950	14
1955	18
1960	27
1965	40
1970	63
1975	82
1980	112
1985	130

Source: Brown 1987.

3. Why do you think grain production is used as an indicator for *total* food production? Do you think this is a good way to estimate food totals? Why or why not?
4. What has been the relationship between world fertilizer use and world grain production? Why would this relationship exist?
5. Why have farmers increased their use of fertilizer?

Most fertilizers used in conventional farming today are manufactured from chemicals. Modern chemical fertilizers are made from so-called fossil fuels—oil and natural gas. Why are these fuels considered fossils?

Table 2 Energy use in world agriculture (millions of barrels of oil)

Year	Fuel*	Fertilizer manufacture	Other**
1950	160	70	46
1960	321	133	91
1970	498	310	162
1980	789	552	268
1985	940	646	317

Notes: **Fuel* = fuel for tractors and other farm machines, including irrigation equipment. ***Other* = energy used to (1) synthesize pesticides, (2) manufacture farm machinery, (3) apply fertilizers, and (4) dry grain. Figures are estimates because no reliable data exist.

Source: Brown 1987.

6. About how many years did it take for the 1950 level of total agricultural energy use to double?
7. About how many more years did it take to double again? What would you predict total energy use to be in the year 2000?
8. What resource do fertilizers, pesticides, and farm machinery all depend on? Is this a renewable resource?
9. Do you think the increasing use of fertilizer is a sustainable practice? Why or why not?

"Mining" water

In what two ways can farmers obtain water for their crops? Would you consider water used by farmers to be a renewable or nonrenewable resource? Why? Under what circumstances would agricultural water supplies be nonrenewable?

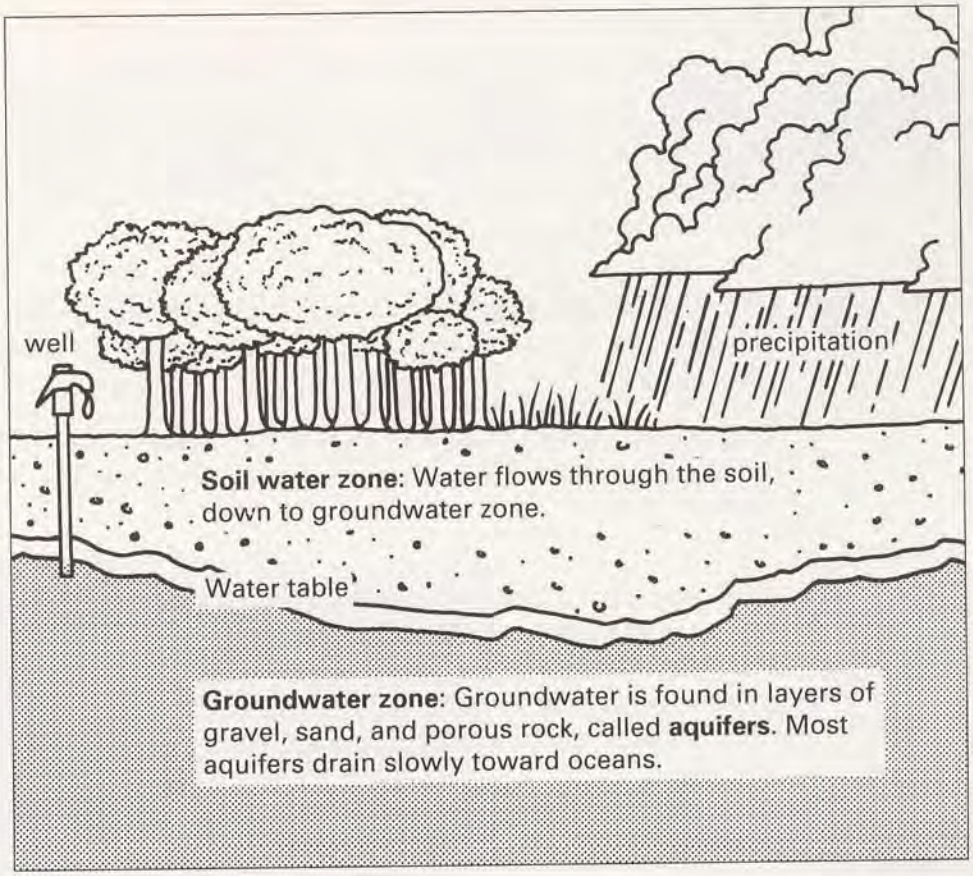


Figure 2 Model of groundwater system, showing how groundwater is obtained (wells) and recharged (precipitation and snowmelt).

> One result [of heavy fertilizer use in Europe, Japan, and North America] is that as much as one-fourth of the nitrogen fertilizers used in these regions leaches into groundwater. Increasing concentrations of nitrates in drinking water, which pose a health threat to bottle-fed infants, have been reported in Denmark, France, the Netherlands, the United Kingdom, and West Germany (Wolf 1987, pages 142–143).

Because aquifers are found in layers of rock far beneath the ground, it is nearly impossible to clean them up once they are polluted by agricultural chemicals (Miller 1986). A different problem can occur with irrigation systems that use groundwater resources. If groundwater is withdrawn through wells at a faster rate than it can be recharged, then the aquifer is depleted. Aquifers can take thousands of years to accumulate. Overusing groundwater to irrigate crops is therefore not a sustainable practice.

Look back at the quote from Eisenberg on page 9. What example of over-withdrawal of groundwater does he give?

"Mining" soil

Soil erosion is also a problem related to conventional agriculture. Is soil a renewable resource? How long would it take to replace the soil lost through poor farming practices? As you read the quote below, consider these two facts:

- In midlatitude regions such as the United States, topsoil develops at a rate of about five tons per acre per year (Steinhart 1983).
- The topsoil depth of the very richest farmland in the United States ranges from 10 inches to less than three feet (Marsh 1987).

> One acre of soil one inch deep weighs about 150 tons. The Soil Conservation Service of the United States estimated in 1979 that an average acre of farmland in the United States lost nine tons per acre per year. How much of the inch of topsoil is lost per year? How much will be lost in 50 years? (Jackson 1980, page 16).

Soil is nonrenewable if erosion happens faster than the ecosystem's ability to create new soil. Also, some farming practices can cause the soil's essential plant nutrients to be used up faster than the soil can replace them. Lesson 3 explores this in more detail.

Wind erosion.

Lesson 3

Why do soils differ from place to place?

Objectives

In this lesson, you will

- Describe and explain world patterns of soil fertility.
- Understand why low soil fertility can limit the agricultural potential of tropical areas.

Glossary Words

humus
leaching
legumes
nitrogen fixation
plant nutrients
soil
soil fertility

Earth's surface varies tremendously from place to place, both in its physical and its human characteristics. Climates, vegetation, and landforms vary; language, beliefs, arts, and economic activities vary. Geographers want to know how these differences occur and why they are important to people. In this lesson, you will explore these questions with regard to soil fertility.

The critical importance of healthy, fertile soil

To understand . . . sustainable agriculture, one must grasp the critical importance of soil. Soil is . . . a complex, living, fragile, medium that must be protected and nurtured to ensure its long-term productivity and stability.

Soybean root nodules contain nitrogen-fixing bacteria.

Healthy soil is a hospitable world for growth. Air circulates through it freely, and it retains moisture long after a rain. A tablespoon of soil contains millions of grains of sand, silt, and clay . . . to which plant nutrients may cling. That same tablespoon of soil also contains billions of microorganisms, including bacteria, fungi, and algae, most of which are principal decomposers of organic matter. Decomposition results in the formation of humus and the release of many plant nutrients. The microbes also produce sticky substances that glue soil particles together and help the soil to resist erosion.

Another essential activity that takes place in the soil is the fixation of nitrogen. Certain bacteria in the soil or in the roots of plants (most notably legumes [such as peas, alfalfa, and soybeans]) convert atmospheric nitrogen gas into fixed forms of nitrogen that plants . . . use to make proteins. The amount of available nitrogen strongly influences soil productivity (Reganold et al. 1990, page 112).

1. How does healthy soil promote plant growth?
2. What is meant by *nitrogen fixation* and why is it important?

Where is soil fertility high? Where is it low?

Geographers study patterns and processes on Earth's surface. Maps help show whether there is a pattern to the locations *where* something occurs. After discovering a pattern, geographers look for the underlying causes that explain *why* the pattern looks as it does. You can use this method to study world soil fertility (Figure 3 on page 18). Soil fertility is the measure of how many essential plant nutrients a soil has. It tells how productive that soil is likely to be for agriculture. If a soil is naturally infertile, it won't be suitable for farming unless expensive fertilizers are added.

Based on the patterns you find in Figure 3, speculate about the causes of the place-to-place differences in soil fertility. Speculation (hypothesizing or guessing) is the heart of geographic inquiry. Making a reasonable guess about the cause of geographic patterns is the first step to finding an answer.

3. Which regions of the world have the highest natural soil fertility?
4. What do these regions have in common? (Consider their latitude, population density, and ability to produce grain crops.)
5. Which regions have soils with naturally low fertility?
6. What do these regions have in common?
7. Which regions have soils that have lost their fertility through overuse? Was the agriculture practiced in these areas sustainable? Explain your answer.
8. Which regions are classified as having only *potentially* high fertility? Why aren't these areas very good for farming?
9. Looking at the areas of high and low fertility, what general conclusion can you make about the location (latitude) of these regions?
10. What climate factor do you think could account for the differences in natural soil fertility that you observed in Question 9? Explain your answer.

SOIL FERTILITY

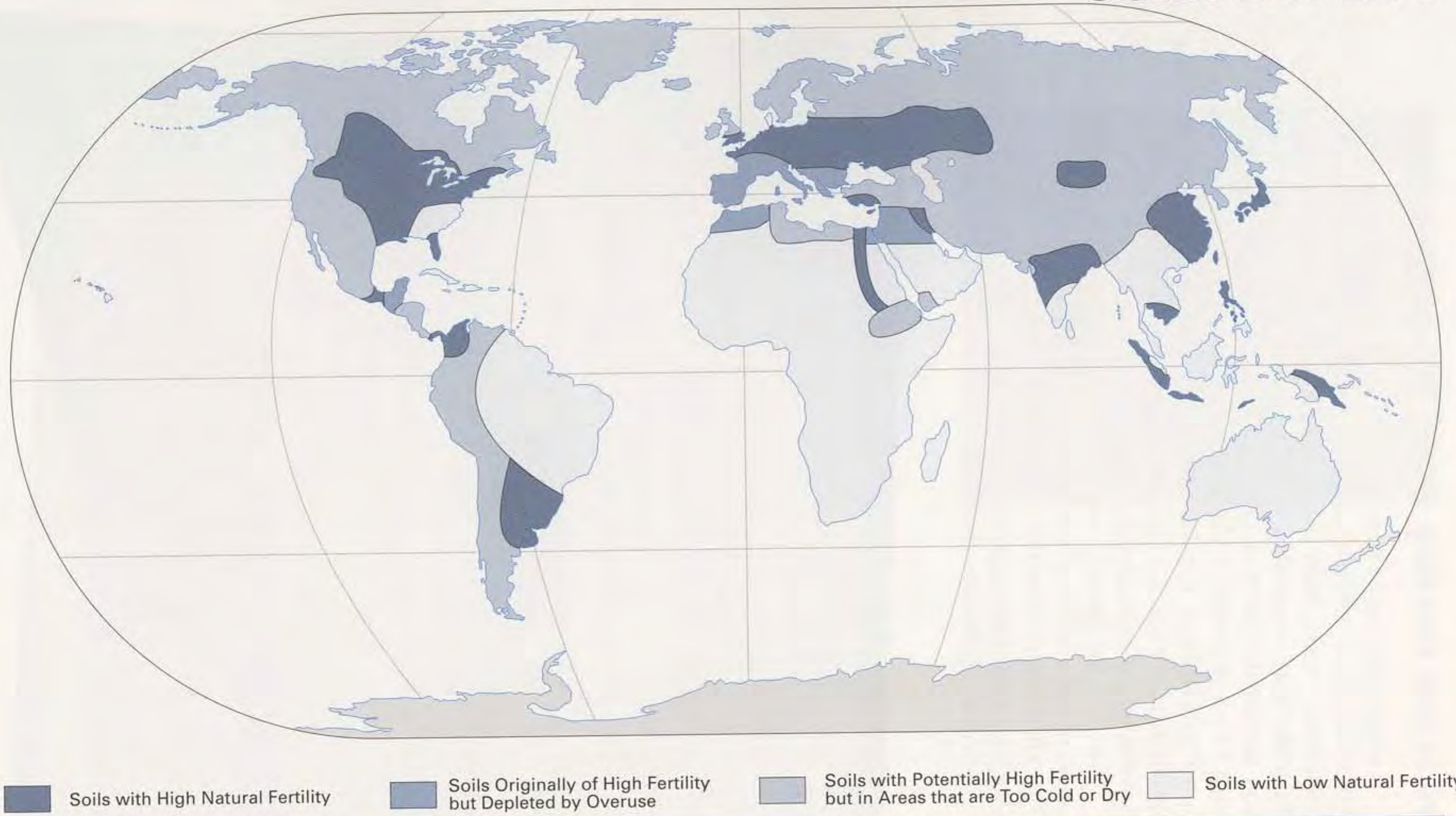


Figure 3 World soils classified by their natural fertility.

Source: Chesworth 1982.

Why does soil fertility vary around the world?

Soil fertility is a measure of how many plant nutrients are available in the soil. Soil forms when rocks at Earth's surface break down into their component minerals. This process takes thousands of years. Rocks break down when exposed to chemical and physical agents. Water is the most important of these agents. Given enough time, water can break down any mineral. As rocks turn into soil, minerals in the rock (such as calcium and potassium) are released, and these nutrients become available to plants. However, the nutrients can be washed away (a process called leaching) if too much water moves through the soil. That is one reason why rainy tropical areas have lower soil fertility.

Soil fertility is also related to a region's average temperature. Temperature is important for two reasons. First, some warmth is needed to weather the minerals out of the rocks. Recall from Figure 3 on page 18 that many areas are too cold to have fertile soils for productive agriculture.

Second, temperature also controls the amount of humus in the soil. Humus is the very fine, decomposed organic matter in soil. It is black, and it is what gives some soils their dark color and earthy smell. Humus is created when soil microorganisms—bacteria, algae, and fungi—decompose plant litter and animal remains. This decomposed organic material is very rich in plant nutrients. The more humus a soil has, the greater its fertility. But how much humus builds up in a soil is related to a region's average annual air temperature (Figure 4 on page 20).

11. Would you expect large amounts of humus to accumulate in tropical soils, such as in the Amazon River basin? Why or why not?
12. Would you expect large amounts of humus to accumulate in midlatitude soils, such as those in the United States? Why or why not?
13. Compare your answers to Questions 11 and 12 to the pattern of soil fertility in Figure 3. How do these answers explain the conclusion you reached in Question 9?
14. How would the characteristics of soil limit agriculture in tropical regions?

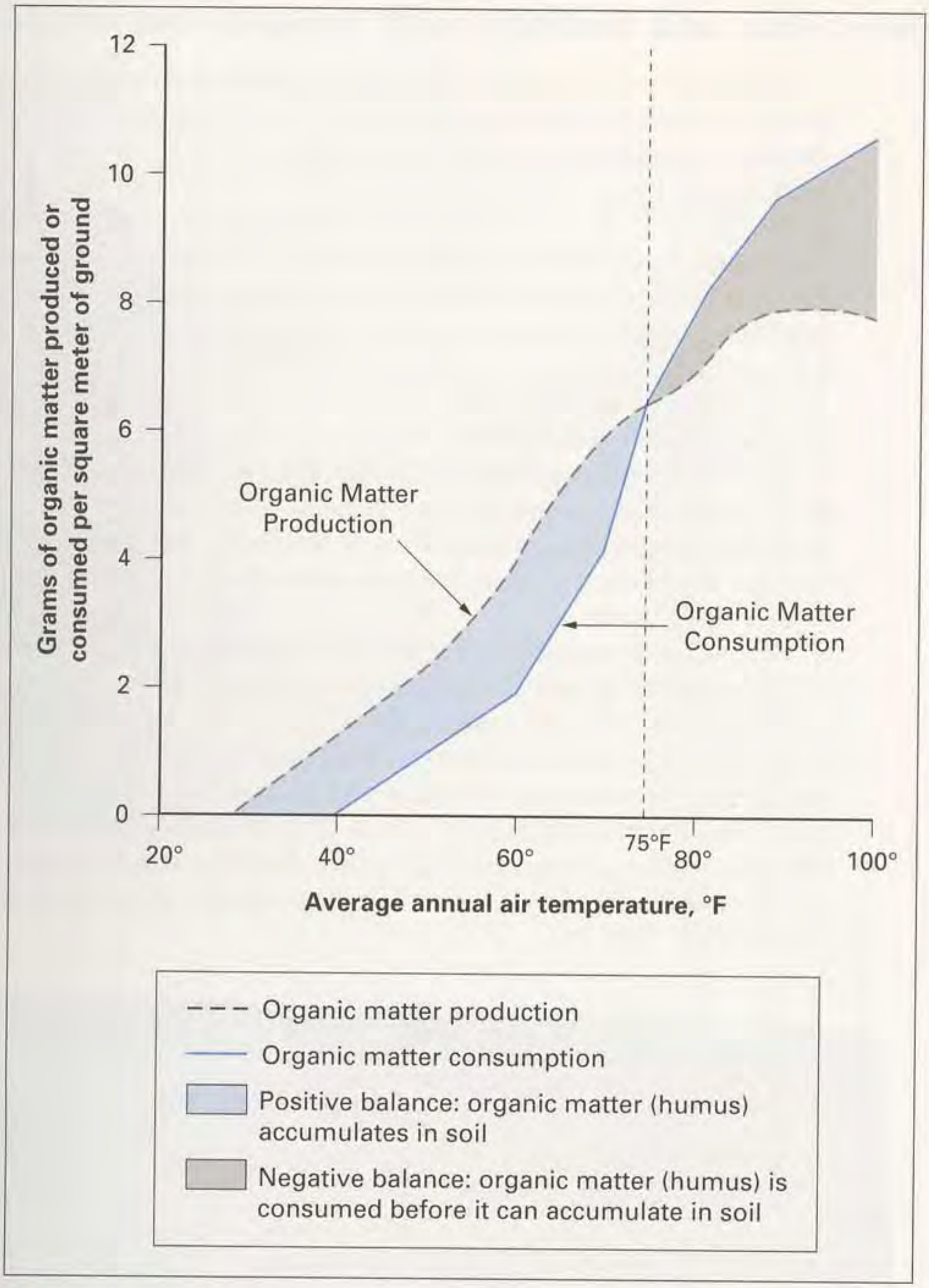


Figure 4 Relationship between humus accumulation and average annual air temperature. Rates of production and consumption of humus (organic matter) in soil are related to the average annual air temperature. At temperatures less than 75°F, organic matter production by plants exceeds the consumption by microorganisms, so humus accumulates in the soil. Above 75°F—the average annual temperature of tropical areas—the rate of consumption is much greater than the rate of production. Because all organic matter is consumed, soils are left with little or no humus.

Source: Marsh 1987.

Lesson 4

What is Malaysia like?

Objectives

In this lesson, you will

- Analyze maps to describe the physical characteristics of Malaysia.
- Analyze data to identify cultural characteristics of Malaysia.

Glossary Words

East Malaysia
monsoon
West Malaysia

In this lesson you begin your case study of sustainable agriculture in Malaysia. It is important to first learn about the physical and cultural characteristics of this country. Physical characteristics of a country include its climate, landforms, vegetation, and soils. Cultural characteristics include where people live and how they make their living.

Malaysia has two parts, West Malaysia and East Malaysia, separated by the South China Sea (Figure 5 on page 22). West Malaysia has 11 states on the Malay Peninsula and is also called *Malaya*. East Malaysia consists of two states, Sabah and Sarawak.

Malaya was a British colony from the nineteenth century until 1957, when it became independent. Sabah and Sarawak were also British colonies, but they were governed separately from Malaya. In 1963, Malaya, Sabah, Sarawak, and the city of Singapore united to form the new country of Malaysia. Singapore withdrew from Malaysia in 1965 and became an independent nation. As you will see, there are major differences between West and East Malaysia.

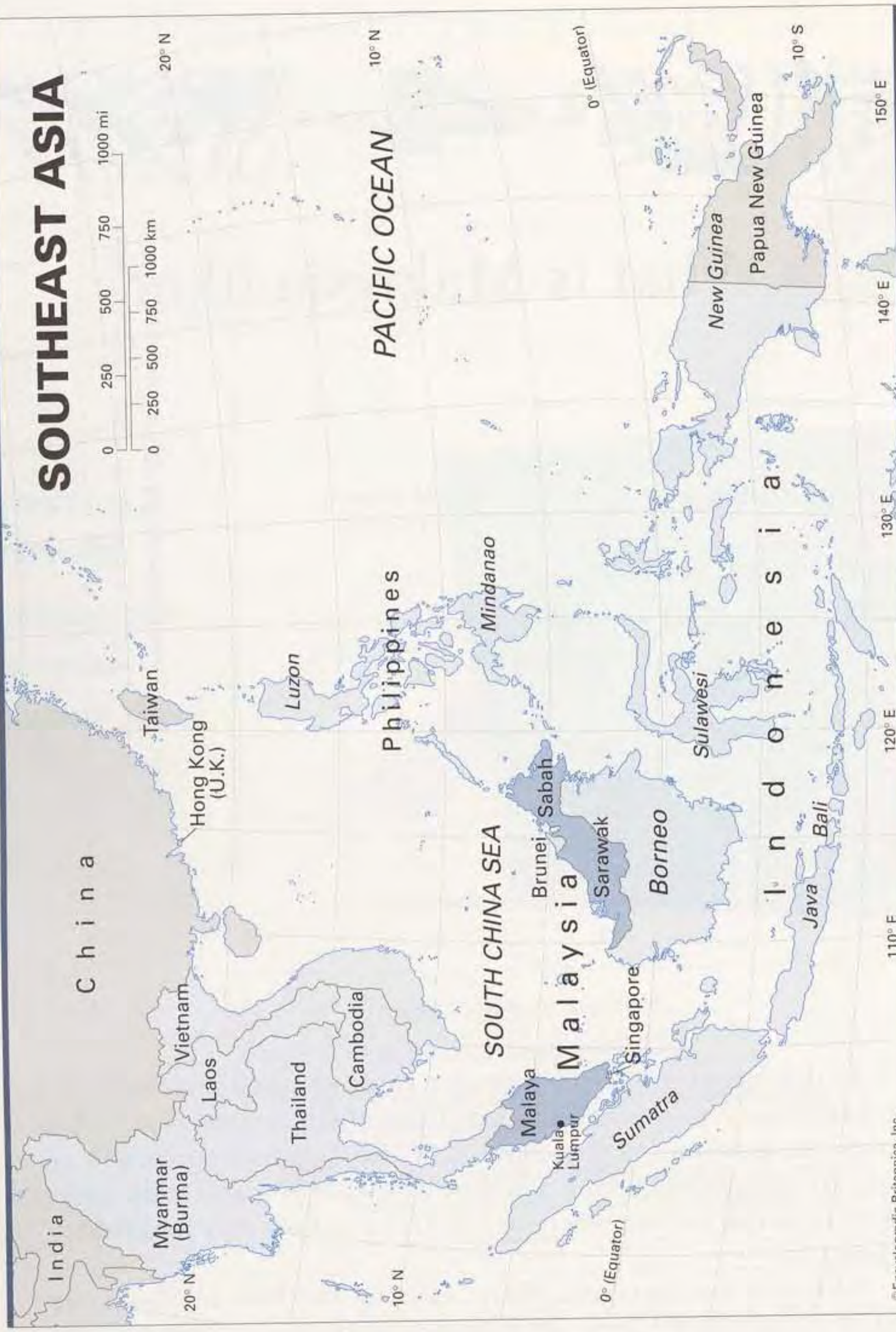


Figure 5 Malaysia, in the region of Southeast Asia.

What are Malaysia's physical characteristics?

Below is a letter from a young Malaysian named Aldyan, who had been in the United States as an exchange student. Aldyan went back to visit his home country, and he sent this letter from Kuala Lumpur, Malaysia's capital, to a friend in the United States. Aldyan's letter is a good introduction to the land and climate of Malaysia.

Kuala Lumpur, West Malaysia
22 June

Dear Tom:

How is your vacation going? I have really enjoyed coming home to Kuala Lumpur. I like going to school in the United States, but it's always good to come home.

As you might imagine, Kuala Lumpur is very warm. Of course, we live at 3 degrees North latitude, so it's warm all the time.

I never realized how much rain we get until I came back home. It's never that hot here though. That's because it's cloudy most of the time. And the clouds at night keep the evenings warm. Also, because we live near the ocean, it doesn't get too cold here.

Today it was about 90 degrees Fahrenheit. It rarely gets hotter than 100 degrees. We spend a lot of time at the beach except during the wet monsoon.

We have the wet monsoon in October and November. It's very windy and it rains all the time. Sometimes we get 50 inches of rain in six weeks, and we'll get more than 80 inches of rain for the whole year. After a while you just learn to ignore the rain.

Later this week we are going to visit my Uncle Turkman in Sabah. He runs a timber business. The state where he lives is the most rugged in all Malaysia. We have to fly over 600 miles to get there, mostly over the ocean.

I wouldn't want to live in Sabah because there are so few people. We have about 19 million people in this country and about 80 percent live here in Malaya. I like living where there are a lot of people. Most of the people in West Malaysia live on farms.

I have to go now. I hope you have a great vacation. Please write me and tell me what's happening in your town. I'll see you when I come back.

Your friend,
Aldyan Diah

1. Across what range of latitude and longitude is Malaysia located?
2. West Malaysia (Malaya) lies on the southern tip of what continent? On what island is East Malaysia (Sarawak and Sabah)?
3. Malaysia has two other independent countries within its borders. Which one is at the tip of Malaya? Which is between Sarawak and Sabah? What other country shares this large island? What other large islands are part of that country?
4. What is the climate of Malaysia? What other places have a similar climate?
5. How much rainfall does Malaysia receive, on the average? During what part of the year does most of this rain occur?
6. What type of vegetation is found in Malaysia? What other places have similar vegetation?
7. What is your image of this type of vegetation?
8. Which areas of the United States might be similar to Malaysia's climate and vegetation? How does your region's climate and vegetation compare to Malaysia's?
9. Is Malaysia mountainous or flat? How would this influence agriculture?
10. Review Figure 3 on page 18. How fertile are Malaysia's soils?

How do most Malaysians make a living?

Table 3 Selected comparisons of Malaysia and the United States, 1992

	Malaysia	United States
Population (millions)	18.7	255.6
Urban population (percent)	35	75
Birth rate (per 1,000 population)	30	16
Death rate (per 1,000 population)	5	9
Years until population doubles*	27	89
Infant mortality rate (per 1,000 live births)	29	9
Total fertility rate (number of children per woman)	3.6	2.0
Population under 15 years old (percent)	37	22
Population over 65 years old (percent)	4	13
Per capita gross national product (U.S. dollars)	2,340	21,700

Source: Population Reference Bureau 1992.
*Indicates years until population would double at current rate of natural increase.

11. What percentage of Malaysia's population lives in rural areas? For comparison, what percentage of the U.S. population is rural?
12. What are the major land uses in West Malaysia? In East Malaysia? Does this make sense, given your answer to Question 11? Why or why not?
13. Compare the data for Malaysia and the United States in Table 3. Which categories seem to have significant differences?
14. Explain how you identified these categories as having significant differences.
15. From the data in Table 3 and your analysis of Malaysia's soils (Question 10 on page 24), what problems might be in store for Malaysian agriculture? Why?

Lesson 5

Is Malaysia's commercial agriculture sustainable?

Objectives

In this lesson, you will

- Understand how tropical forest ecosystems influence farming practices.
- Identify the main parts of Malaysia's agriculture.
- Describe how agriculture differs between West and East Malaysia.
- Explain how Malaysian farming practices affect the environment.

Glossary Words

agricultural system
arable land
cash crops
commercial agriculture
East Malaysia
ecosystem
fallow
humus
leaching
legumes
manuring
nutrient cycling
plant nutrients
soil
soil fertility
subsistence agriculture
West Malaysia

How do tropical forest ecosystems work?

You have seen (Figure 3 on page 18) that natural soil fertility differs between the midlatitudes (such as the mainland United States) and the tropics (such as Southeast Asia). There are also major differences in how plant nutrients move between soils and plants. *Nutrient cycling* refers to the way essential nutrients (including nitrogen, phosphorus, and potassium) flow through an ecosystem. These flows go through soils into plants, from plants to animals, and from one generation of plants to the next. Looking at nutrient cycling is important for understanding the agriculture of tropical countries like Malaysia.

The floor of a forest is usually covered with a layer of dead leaves, branches, and logs. This layer is called *litter.* Litter drops to the soil when plants die or when they shed leaves and branches. Soil microorganisms slowly decompose this organic litter into humus. In midlatitudes, the rate of decomposition is slower than the vegetation's production of litter. So, in midlatitude forests, soils often have a lot of humus. The next generation of plants gets essential nutrients directly from the humus-rich soil.

But forest ecosystems work differently in the tropics. In warmer climates, decomposer microorganisms in soil are very active (Figure 4 on page 20). They completely consume organic litter, so humus cannot build up in the soil. So, plants cannot obtain nutrients directly from the soil. Also, heavy rains, typical of moist tropical climates, often wash away whatever nutrients are present in the soil. As a result, tropical soils are actually very poor in plant nutrients. Yet when you think of the tropics, you probably imagine lush rainforests. How can there be so many plants if the soils are so infertile?

Here's the key: In the tropics, the nutrients are stored above the ground—in the vegetation itself—not in the soil (Walter 1979). When plants shed leaves and branches, the litter drops to the soil, just as in the midlatitudes. But tropical plants are adapted to obtain essential nutrients from this litter *before* the decomposer organisms completely consume it. The next generation of plants grows from the nutrients supplied directly by the older plants. There is no humus, but there is also very little litter accumulated on the forest floor. Essential nutrients are cycled among the plants very quickly. This guarantees the survival of tropical forests.

1. Trees in tropical rain forests do not lose their leaves because of seasonal changes in temperature. What other factors might cause leaves and branches to fall to the ground in tropical forests?
2. Why is knowledge of nutrient cycling important to agriculture?
3. What are some of the problems that might be caused by cutting down tropical forests?

What major crops are grown in Malaysia?

Commercial crops, also known as cash crops, can be grown either for domestic use or for export. Cash crops that are exported are important sources of income for countries. All commercial crops are dependent on markets. Like U.S. farmers, farmers in Malaysia grow commercial crops as long as they can earn money from them. If farmers cannot sell certain crops, they must grow other crops that will sell.

Most of Malaysia isn't suitable for farming because of the dense forests, mountainous terrain, and infertile soils. The best agricultural soils in the country are usually on hillsides. In the lowlands, poor drainage can leave places waterlogged, which kills roots.

Table 4 below shows which crops were important exports for Malaysia in 1971 and 1982 (the last year for which complete numbers are available). By the mid-1980s, Malaysian farmers had almost 5 million acres devoted to rubber trees. They had about 3 million acres each planted in rice and oil-palm trees and about 300,000 acres under cultivation for all other crops (Kurian 1987). Export markets for Malaysian products were good, but the Malaysian government wanted the country to be self-sufficient in food production. In 1980, about 22 percent of the total value of exports had to be spent on importing food (Bunge 1985).

Table 4 Exports of principal Malaysian crops, 1971 and 1982

	Amount produced (thousands of tons)		Percentage of crop exported in 1982
	1971	1982	
Rubber	1,287	1,378	100
Palm oil products	507	3,966	75
Coconut products	122	89	100
Rice	1,088	1,314	0

Source: Bunge 1985.

4. During the period shown in Table 4, which crop had the largest increase in production? Which crops stayed about the same?
5. Why do you think none of Malaysia's rice was exported?
6. During World War II, U.S. scientists invented synthetic rubber because the United States could not get natural rubber from Malaysia (Japan controlled the region). How would this invention affect rubber production in Malaysia?
7. What is palm oil used for? What might cause world demand for palm oil to increase or decrease? Can you think of any way that your own family's actions influence this market?
8. According to Figure 6 on page 30, how does the status of farmland differ between West and East Malaysia?
9. Which region, West or East Malaysia, seems to be more important to Malaysia's commercial agriculture? Why do you think it is?

Rubber tapper collects latex from a small cup on the trunk of a rubber tree.

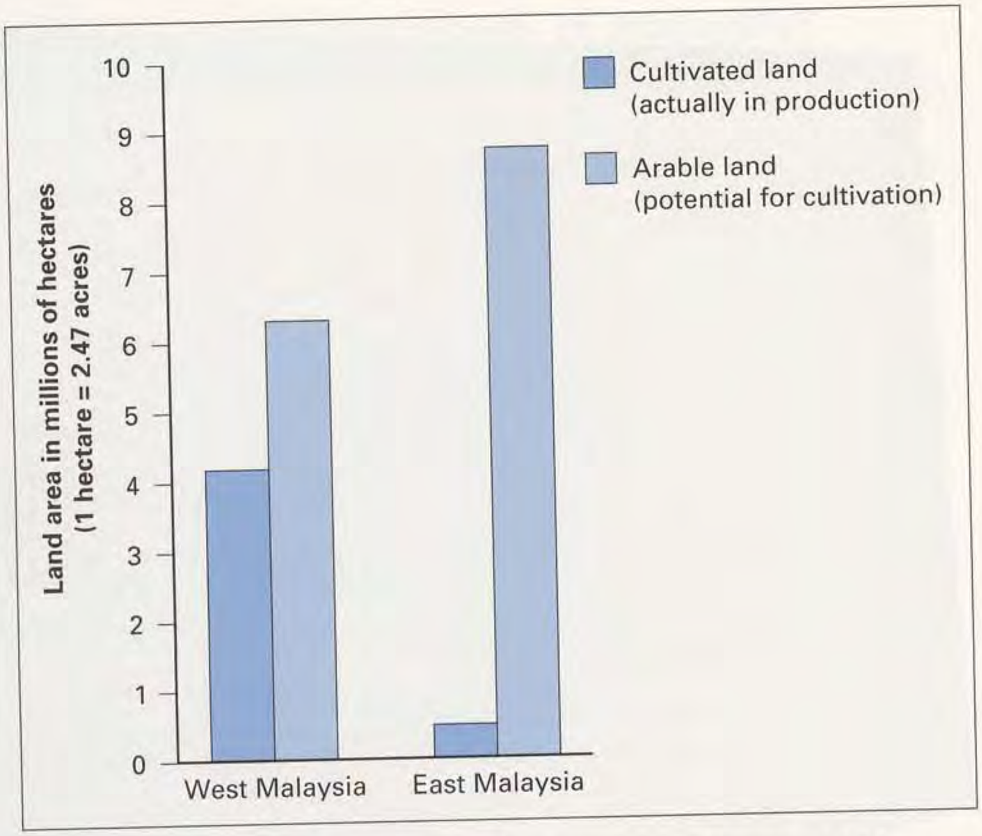


Figure 6 Cultivated and arable land by region in Malaysia, 1979.

Source: Bunge 1985.

How are Malaysia's major crops grown?

The following pages give brief descriptions of four major agricultural systems in Malaysia. As you read, consider these questions:

10. If you were a Malaysian farmer, which of the four systems would you choose? Why?
11. What steps do Malaysian farmers take to sustain soil fertility for each of the four systems?
12. Are there environmental problems associated with any of these systems? If so, what are they and which system causes the most problems?
13. Are all these systems sustainable? Why or why not?

Agricultural systems for domestic food

Rice

Rice is the main food of Malaysia. Most of Malaysia's rice is planted in irrigated or flooded fields, known as paddies (this word is derived from the Malay word for rice, *padi*). Most paddies produce two rice crops per year. The best rice farming areas are on the Malay Peninsula. Rice farmers there grow new, higher-yielding breeds of rice, which were developed by scientists. Most rice cultivation in East Malaysia uses dry-land methods, which do not yield as much rice (Bunge 1985).

The most common method of growing rice begins when a paddy to be planted with rice is burned. Then it is flooded and the vegetation left to rot. The field is plowed several times to mix the rotting vegetation in order to resupply the soil with nutrients. Rice seedlings are brought in from a nursery. They are planted in two inches of water. The water helps prevent weed growth. Later, when the leafy adult plants create too much shade for weeds to grow, the fields are drained. Rice is harvested in the dry season so it can be dried before being milled. Manure is spread if necessary to replace lost soil nutrients.

Rice is grown entirely for use within Malaysia. Nearly all of Malaysia's domestic needs for rice are met by small landholders, but 10 percent of the country's rice must be imported from Thailand. World prices for rice are usually quite low, so a farmer can make more from an acre of rubber or oil-palm trees than from rice. However, rice is always in demand because it is the main food consumed by Malaysians (Ooi Jin-Bee 1976).

Shifting cultivation

In 1980, the U.N. Food and Agriculture Organization estimated that about 1.7 million people in Sabah and Sarawak relied on *shifting cultivation*. Only about 50,000 people in West Malaysia also still use this ancient system of raising food (Bunge 1985). Most shifting cultivators don't produce commercial crops sold on the market. Rather, they grow only enough food for their own families and communities. This is known as subsistence agriculture.

Under shifting cultivation, only about 10 percent of the land is actually farmed in any given year. The remainder is left fallow (no crops planted), allowing natural vegetation to grow. A plot of land is cropped for a year or two, then left alone for at least 10 years while the vegetation recovers. Then the farmer burns the vegetation, enriching the soil's fertility with the ashes. Crops are then planted for a year or two. Then the cycle is repeated: The first plot is left fallow and cultivation shifts to another plot. This method has sustained agricultural production for thousands of years in tropical areas throughout the world.

Most people using shifting cultivation grow staples such as rice and cassava. (The root of the cassava plant is eaten as a starch and used to make products like tapioca.) Other important staple crops are maize and yams. Yet the shifting cultivation method is not as productive, per unit area of land, as other means. Because only 10 percent of the land is actually farmed, shifting cultivation requires more land than modern commercial farming to produce the same amount of food. The governments of Sabah and Sarawak have developed policies to encourage shifting cultivators to convert to commercial agriculture and grow rubber trees and other cash crops. There is little information on how successful this program has been (Bunge 1985).

Agricultural systems for export crops

Rubber

The rubber tree was introduced to Malaysia from Brazil in the late 1800s. Soon afterward, the automobile and the pneumatic tire were invented and rubber became a valuable export. Malaysia has been the world's largest producer of natural rubber for many years. It supplies roughly 50 percent of the world's trade in rubber. Nearly all of the production comes from West Malaysia (Bunge 1985).

Rubber trees are resistant to insect pests. They grow well in soils high in clay—which are typical of the tropics—provided the area is well drained. Rubber trees are raised from seed in nurseries and planted as saplings. Nitrogen is an essential nutrient for rubber trees. Crops that fix nitrogen (convert atmospheric nitrogen into a form usable by other plants), such as legumes, are planted around the young trees. The legumes also prevent erosion by covering the ground. Farmers also plant other crops around the young trees as ground cover. These crops provide the farmer with some income until the rubber trees are mature. Cassava, pineapple, and bananas are typical ground-cover crops. After three years, the growing rubber trees create too much shade and the ground-cover crops are discontinued.

Rubber trees begin producing commercial quantities of rubber when they are about five years old. They live for 25 or 30 years. After about 30 years, rubber trees need to be replanted, which exposes the land to severe erosion (Brookfield et al. 1990). Another problem with rubber farming is that the waste from processing rubber is dangerous and hard to dispose of safely (Ooi Jin-Bee 1976). Finally, rubber farming is highly influenced by world markets. If the price goes down, rubber farmers can go broke. For example, when the world automobile industry declined in the early 1980s, many small rubber farmers in Malaysia went bankrupt. Many rubber farms were abandoned and people migrated to the cities. Other rubber plantations were converted to grow oil palms. Oil-palm trees take about half as much time to mature as rubber trees, and prices for palm oil remained strong (Bunge 1985).

Palm oil

Malaysia is the world's largest producer of palm oil. Nearly 80 percent of the world's supply comes from Malaysia (Bunge 1985). Palm oil is the fat pressed from the fruit of the oil-palm tree. It is used in many products, including margarine, fats, soaps, lubricants, and plastics. New uses are being invented. In the 1980s, palm oil replaced rubber as Malaysia's highest-value export. The strong world demand for palm oil inspired many rubber farmers to change over to oil palms. Rubber plantations can be quickly converted to oil palms.

The oil palm grows well in Malaysia and requires less maintenance than rubber trees. However, the palm tree is sensitive to drought and needs regular rainfall. Like rubber trees, oil palms are very hardy and resistant to pests and disease. Malaysian farmers have learned to increase production by introducing insects to pollinate the trees.

Fruits of the oil palm will be bagged and shipped to the processor for production of palm oil.

The oil palm is grown from seed in a nursery and planted as a young tree. As with rubber, it is normal to plant legumes, such as clover, around the tree for nitrogen supplies. Legumes also act as a ground cover to prevent erosion. The tree begins to bear fruit in its third year and lives about 30 years. Typically the palm causes the soil to lose some fertility, which can be replaced by occasional manuring. Other than this, there is little farmers need to do to raise oil palms. The tree produces fruit year round. Therefore, palm cultivation requires fewer workers than does rubber. However, palm oil must be processed quickly or it becomes unusable. The machinery to produce it is also expensive. There are some other drawbacks to farming oil-palm trees. The waste from oil production is harmful and difficult to dispose of. And if world demand for palm oil should decrease, farmers cannot make money (Ooi Jin-Bee 1976). For example, it has been found that palm oils are high in cholesterol, which means the demand for food products made from palm oils may be decreasing.

Soil erosion under oil palms, which develop a dense canopy to catch raindrops, is much lower than under rubber trees. But oil-palm trees deplete soil fertility more than rubber trees do. After about 30 years, oil-palm trees need to be replanted, which again exposes the land to soil erosion (Brookfield et al. 1990).

Are these agricultural systems sustainable?

Most farms in Malaysia are small. Farmers use varying levels of modern technology to grow crops, depending on how close they are to markets. In Malaysia, however, the long-term trend is toward increasing use of technology to produce cash crops for export.

The most important factor determining production has been the supply of water. The Malaysian government has supported major irrigation projects to increase rice production. Projects to help the drainage of flatland soils, which can become waterlogged in the wet climate, have also been established. This is necessary because many tree crops (such as rubber and oil palm) can be damaged by waterlogging (Bunge 1985).

Other methods have been introduced to improve farm production, namely,

- high-yielding varieties of crops,
- chemical fertilizers,
- mechanized farm equipment, and
- new farming techniques.

Some results of these programs are shown in Figure 7 below. Which of these trends seem to be sustainable? Which do not? Additional data (Figures 7–9 and Tables 5–6) are presented on pages 35–38 to help you consider whether or not commercial farming in Malaysia is sustainable.

Review these data and the information from the readings in this lesson. Decide whether or not Malaysia is, in effect, "mining" its soils, water, and fossil fuel resources to support its commercial agriculture.

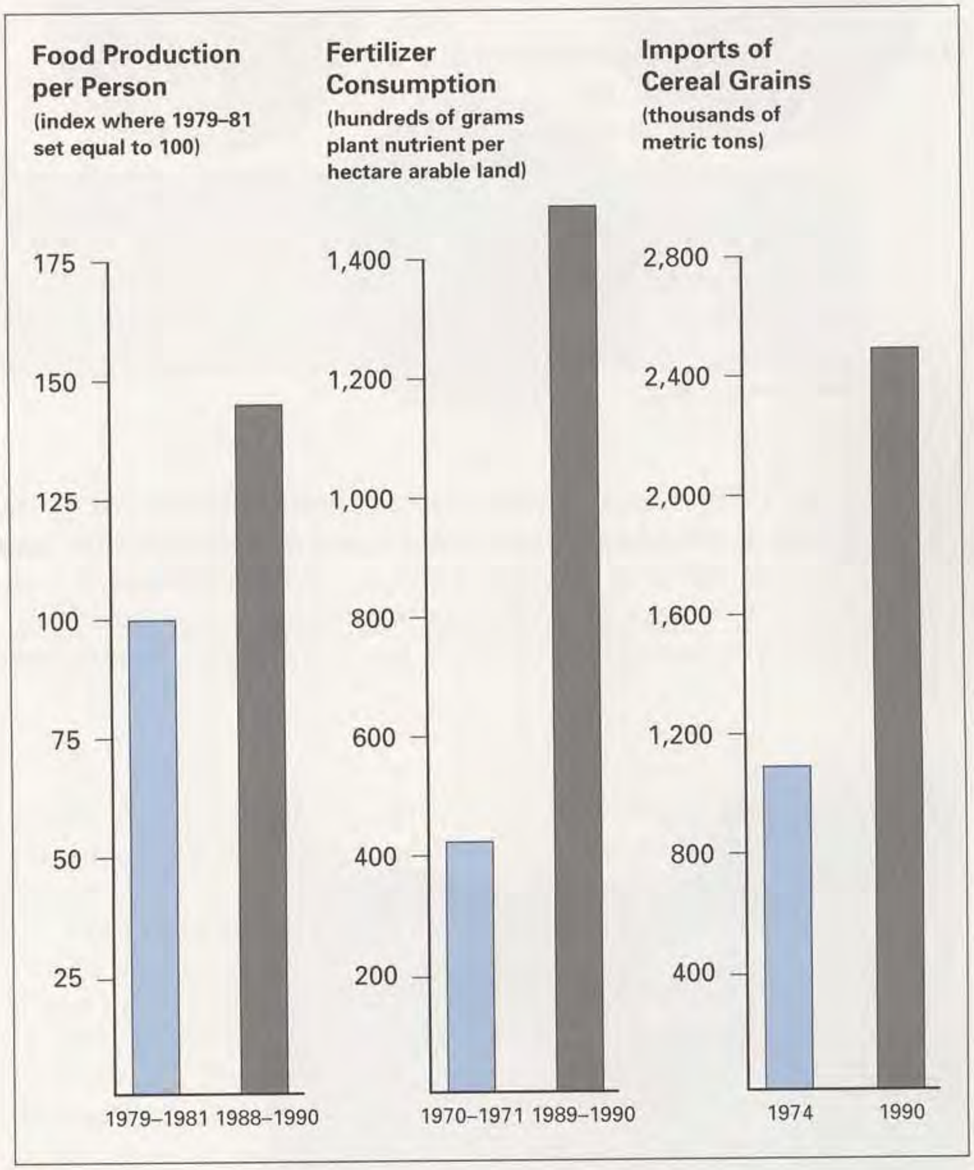


Figure 7 Trends in Malaysian agriculture, 1970s to 1990s.

Source: World Bank 1992.

Table 5 Population projections for Malaysia to 2025

Year	Population estimate (millions)
1992	18.7
2010	27.1
2025	34.9

Source: Population Reference Bureau 1992.

Table 6 Malaysia's production and exports of petroleum, 1971 and 1983 (thousands of barrels of oil)

	1971	1983
Production	11,672	139,284
Exports	5,566	102,957

Source: Bunge 1985.

In 1950, tropical forests covered about 73 percent of the Malay Peninsula (Brookfield et al. 1990). Since then, much of the forest has been cleared for agriculture, mainly to grow oil palm and rubber (Figure 8 on page 37). Although logging has been destructive, converting forests to plantations has created much wealth, both for

Malaysian rain forest cleared for rubber plantation.

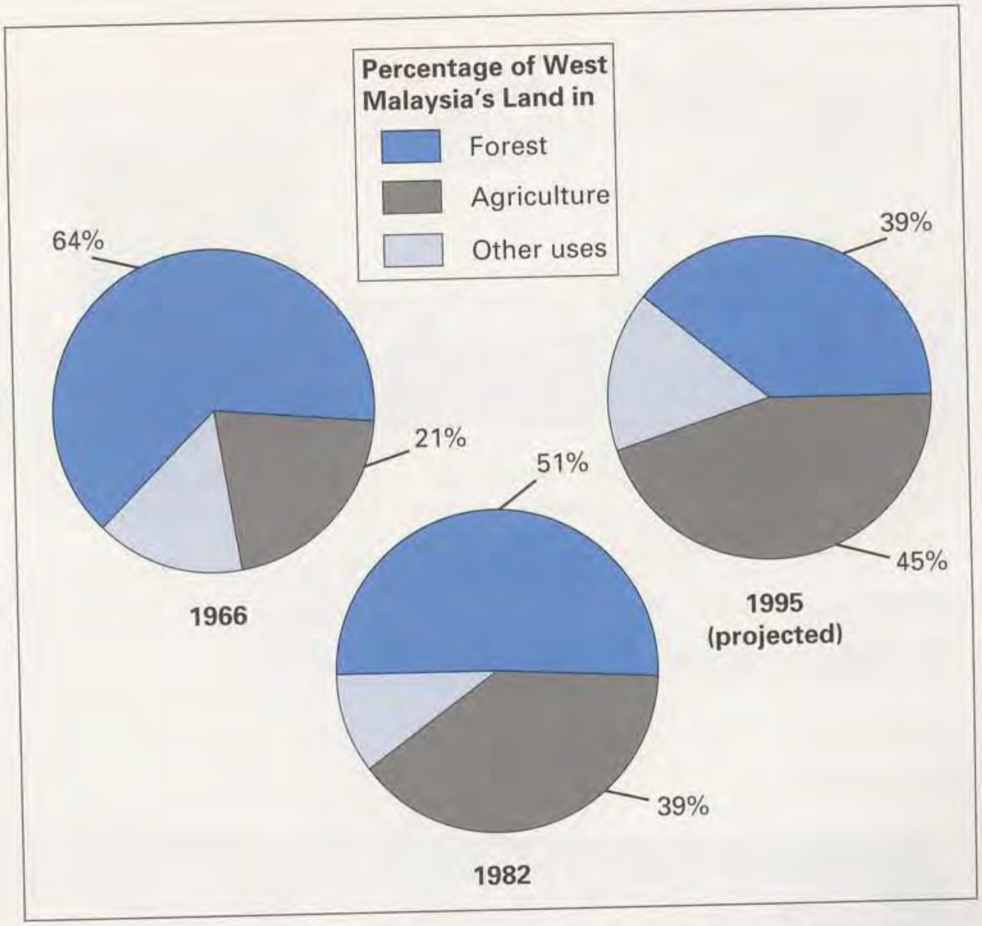


Figure 8 Conversion of forest land to agriculture in West Malaysia, 1966 to 1995.

Source: Brookfield et al. 1990.

foreign investors and for many Malaysians. This fact needs to be remembered when looking at the environmental changes that have occurred.

The loss of forest cover means that the few nutrients in the soil can be leached away. Also, removing the forest cover makes soil prone to erosion from the heavy rains. Erosion is a serious problem in many ways. Eroded soil washes into streams, raising the level of the riverbed. This process is called siltation (Figure 9 on page 38). During the rainy season, the shallower rivers cannot handle the higher stream-flow, and severe floods can occur. In the dry season, there may not be enough water in the stream to flow through the silt deposits. This has led to water shortages in some communities (Brookfield et al. 1990).

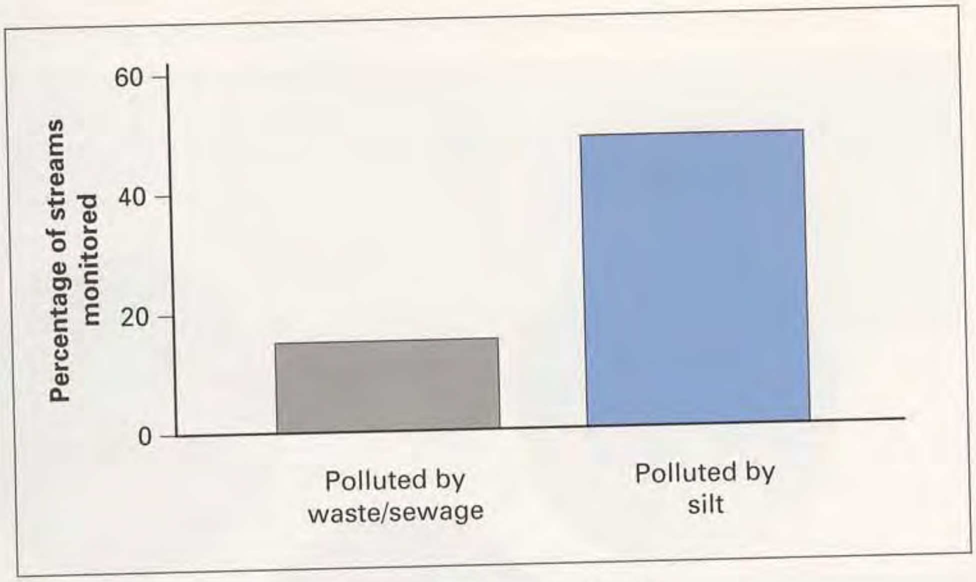


Figure 9 Sources of stream pollution in Malaysia.

Source: Sani 1988.

14. Why are population data (Table 5 on page 36) important for thinking about agricultural sustainability?
15. Why are data for petroleum (Table 6 on page 36) helpful for considering whether modern farming practices are sustainable?
16. What would be a good way to show or describe the increases in production and export of petroleum from 1971 to 1983? Why?
17. Which pollutes more streams, sewage or silt (Figure 9 above)? Why is silt considered a pollutant? What environmental damage does silt cause?
18. What causes silt pollution in Malaysia? How is this related to the issue of sustainable agriculture?
19. Did your opinion about whether Malaysia's farming practices are sustainable change as a result of looking at these data? Why or why not?

Lesson 6

Can agriculture in Africa be made sustainable?

Objectives

In this lesson, you will

- Map patterns of population growth to determine where increased agricultural productivity is most needed.
- Understand how traditional farming systems can be used to develop sustainable agriculture in tropical areas.

Glossary Words

agroforestry
doubling time
fallow
humus
nitrogen fixation
soil fertility

Which regions need better agricultural productivity?

Recall from Lesson 1 that to be sustainable, agriculture must both conserve the resources of the physical environment and, *at the same time*, produce enough food to meet the needs of the population (Altieri 1987). You have already seen what types of agricultural practices sustain the physical environment. But as the world's population grows, farmers must be able to produce more food. What must be improved is agricultural productivity: the ability of farms to produce food. Can this be done without destroying the environment? Before you examine this question, consider this first: Where is the greatest need for improved agricultural productivity?

African woman prepares food for her family.

Table 7 below shows the doubling time for population in each of 11 world regions. Doubling time tells how many years it will take for the population to double. For instance, the population of the United States and Canada together is now 283 million. According to Table 7, the total population of the United States and Canada will double (to 566 million) in 89 years. This assumes that present birth and death rates stay the same over that time.

Table 7 Doubling times for population by world region

Region	1992 population estimate (millions)	Years for population to double, at current rate of natural increase
East Asia	1,262	57
South Asia	1,231	31
Europe	511	338
Africa—South of the Sahara	507	23
Latin America	453	34
Southeast Asia	451	36
North Africa/Southwest Asia	286	25
Former Soviet Union	284	104
United States/Canada	283	89
Japan	124	217
Australia/New Zealand/Pacific	28	57

Source: Population Reference Bureau 1992.

1. How is population growth related to the need for greater agricultural productivity?
2. Which areas are growing faster: those with a low doubling time, or those with a high doubling time?
3. Compare the pattern of doubling time to the pattern of world soil fertility (Figure 3 on page 18). Which areas have both rapid population growth and poor soils?
4. Why would those areas have the greatest problem in improving agricultural productivity?
5. What is the problem with grouping data on population growth by region, as is done in Table 7? What additional kinds of information might be important to have?

How can productivity be increased in tropical areas?

Recently, scientists have realized that tropical farming systems that were used for thousands of years must have managed soil, water, and nutrient resources carefully. In other words, traditional methods of tropical agriculture may provide techniques to make modern farming sustainable (Wolf 1987).

In tropical areas with nutrient-poor soils, intensive monocropping quickly robs soil of its fertility. Instead, farmers must plant a variety of crops and rotate these crops. This method allows essential nutrients enough time to be renewed. Traditionally, shifting cultivation used this approach. But shifting cultivation requires large amounts of land. Often rapid population growth forces farmers to return too soon to fallow fields or forces them onto marginal lands. When this happens, shifting cultivation can cause major environmental damage.

African scientists have adapted the principles of shifting cultivation to modern conditions. This technique is known as agroforestry. Agroforestry maintains forests, renews soil fertility, and yields more food than traditional shifting cultivation (Wolf 1987).

The basics of agroforestry are simple. Field crops are grown between rows of nitrogen-fixing trees. Tree crops, such as oil palms, fruit trees, and coffee, are also grown. Leaves from the trees add humus to the soil. Certain trees also add nitrogen to fertilize the soil, cutting the need for expensive fossil-fuel chemicals. Crops can be grown continuously, without a fallow period. Pests are controlled by natural means, by introducing beneficial insects that eat the harmful insects. Forests are preserved instead of cleared. The need for chemical fertilizers and pesticides is reduced. And enough food can be grown to feed growing populations (Wolf 1987).

Figure 10 on page 43 is a sketch of an agroforestry system being used successfully in the western part of the country of Cameroon. The sketch shows many practices that are designed to improve productivity while sustaining the environment. Figure 11 on page 44 provides more detail. How does each practice help make this technique sustainable?

Agroforestry in Western Africa.

Key

1 Agroforestry sector
2 Oxen shed and roofed-over manure storage area
3 House garden
4 Legume hedges
5 Fallow plot (fallow for one year; crops planted every other year)
6 Contour ridges that follow slope of hillsides (Figure 11 on page 44)
7 Planted field strips atop contour ridges (Figure 11 on page 44)
8 Pasture planted in high-yielding grasses and legumes
9 Weed control using oxen

Figure 10 Sketch of an agroforestry system in Cameroon.

Source: Prinz and Rauch 1987.

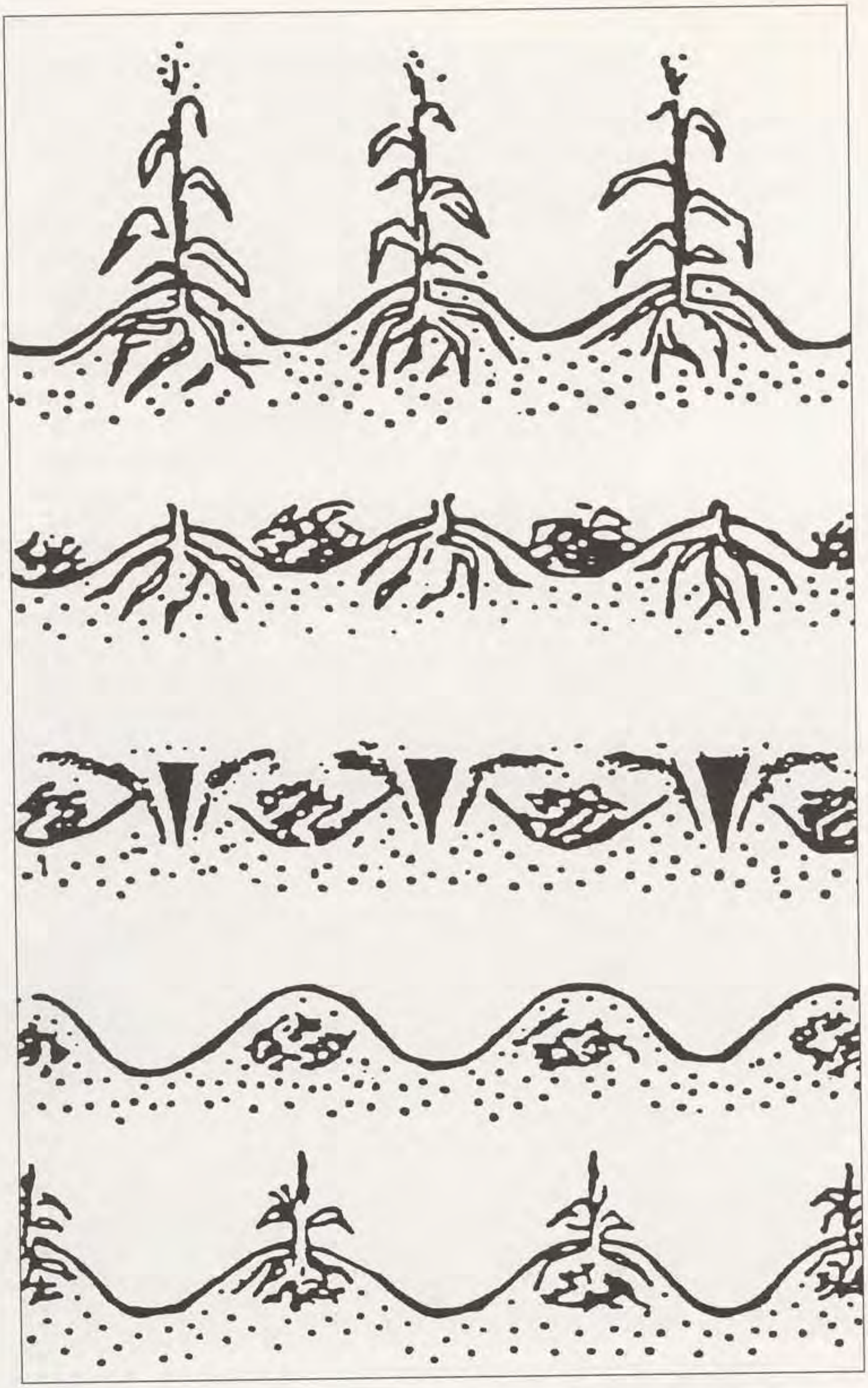


Figure 11 Detail of contour ridges and planted field strips from Cameroon system. Ridges are about three feet wide and two feet high, separated by about 15–20 feet.

Source: Prinz and Rauch 1987.

Lesson 7

Is conventional farming in the western United States sustainable?

Objectives

In this lesson, you will

- Understand the problems of conventional farming in the western United States.
- Explain why U.S. farmers expanded production onto arid lands.
- Analyze whether sustainable agriculture makes economic sense.

Glossary Words

aquifer
cash crops
fodder
herbicide
legumes
marginal land
monocropping
nonrenewable resource
pesticide
soil
topsoil

What environmental problems does farming cause on arid western lands?

Conventional farming in the United States efficiently produces tremendous quantities of food. Yet some farming systems in the United States create environmental problems. Try to answer the questions on page 46 after you have studied Figure 12.

WIND EROSION POTENTIAL

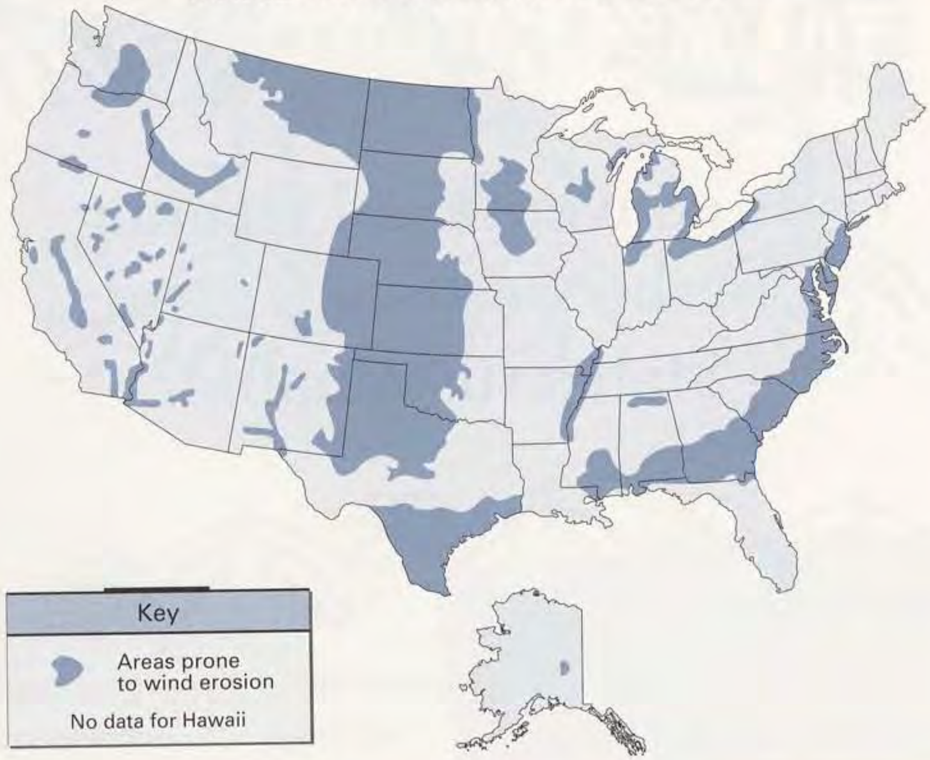


Figure 12 U.S. cropland areas with highest potential for soil erosion by wind. Dark areas are most subject to wind erosion.

Source: World Eagle, Inc. 1990.

1. In which areas (Figure 12 above) is the potential for soil erosion by wind greatest?
2. What are three reasons why wind can erode soils in these regions?
3. How would extensive farming increase wind-caused erosion?

Farms in arid and semiarid areas rely on groundwater resources (aquifers) to irrigate the land. The largest of these underground sources is the Ogallala Aquifer on the western Great Plains. Expansion of farming in this area has severely reduced the level of this nonrenewable groundwater resource. In the United States, the groundwater level is falling beneath 40 percent of the irrigated farmland. In some cases, the level is dropping several feet per year (Brown 1987).

Here's a graphic example of what drought can really mean.

When the Soil Blew Away

On a December morning in 1977, Sheriff Larry Kleier drove his patrol car southeast from Bakersfield, California, into the Tehachapi Mountains. It was a cold, clear day, but unusually windy. It was the second year of drought, and the farmlands of the San Joaquin Valley were gray and blistered. . . .

As he drove up a ridge, Kleier saw only blue sky and sunlight over the hood of the car. But when he started down into a valley, everything changed. "Just as I came over the hill," he says, "it was like someone turned off the lights." The wind became extremely violent, and an enormous dust cloud enveloped the car. "I started trying to find a way to go back, but I couldn't stop or turn around. I heard the traffic going by on the other side of the road, but I couldn't see it."

A sudden burst of wind raked the windshield with rocks and gravel, instantly frosting it milky white. Kleier could barely see the end of the hood. . . . "And . . . the rocks started breaking my windows." First the back window shattered. Then the side windows. Dust filled the car. The radio stopped working. It was hard to breathe. . . .

Outside, the dust tore open the countryside. Winds over 100 mph broke wooden telephone poles and buckled steel powerline supports. . . . Cattle suffocated in the dust at fencelines and were found with the hair and skin sandblasted off their hindquarters. The wind spaded two feet off the tops of freshly plowed fields, lofted the soil high into the atmosphere, and carried it hundreds of miles. It came down days later as red rain in [northern California]. . . .

The volume of dust moved by the storm was due much to human activities. Geologists estimate that the winds carried 25 million tons of soil from the foothill areas that the California Department of Conservation had warned were "consistently overgrazed." On the hills, you could look down fencelines and see that heavily grazed lands had lost their topsoil, while on less intensively grazed lands across the fence, both grass and soil were still in place. The geologists estimated that another 25 million tons of soil blew off the freshly plowed fields of the valley. They noted that in recent years the farmers had torn out the windbreaks planted in the 1940s to contain wind erosion (Steinhart 1983, pages 94–95).

What motivated California ranchers to graze their lands too heavily? Why do you think farmers destroyed the windbreaks that contained wind erosion?

Why are marginal lands in the western United States used for agriculture?

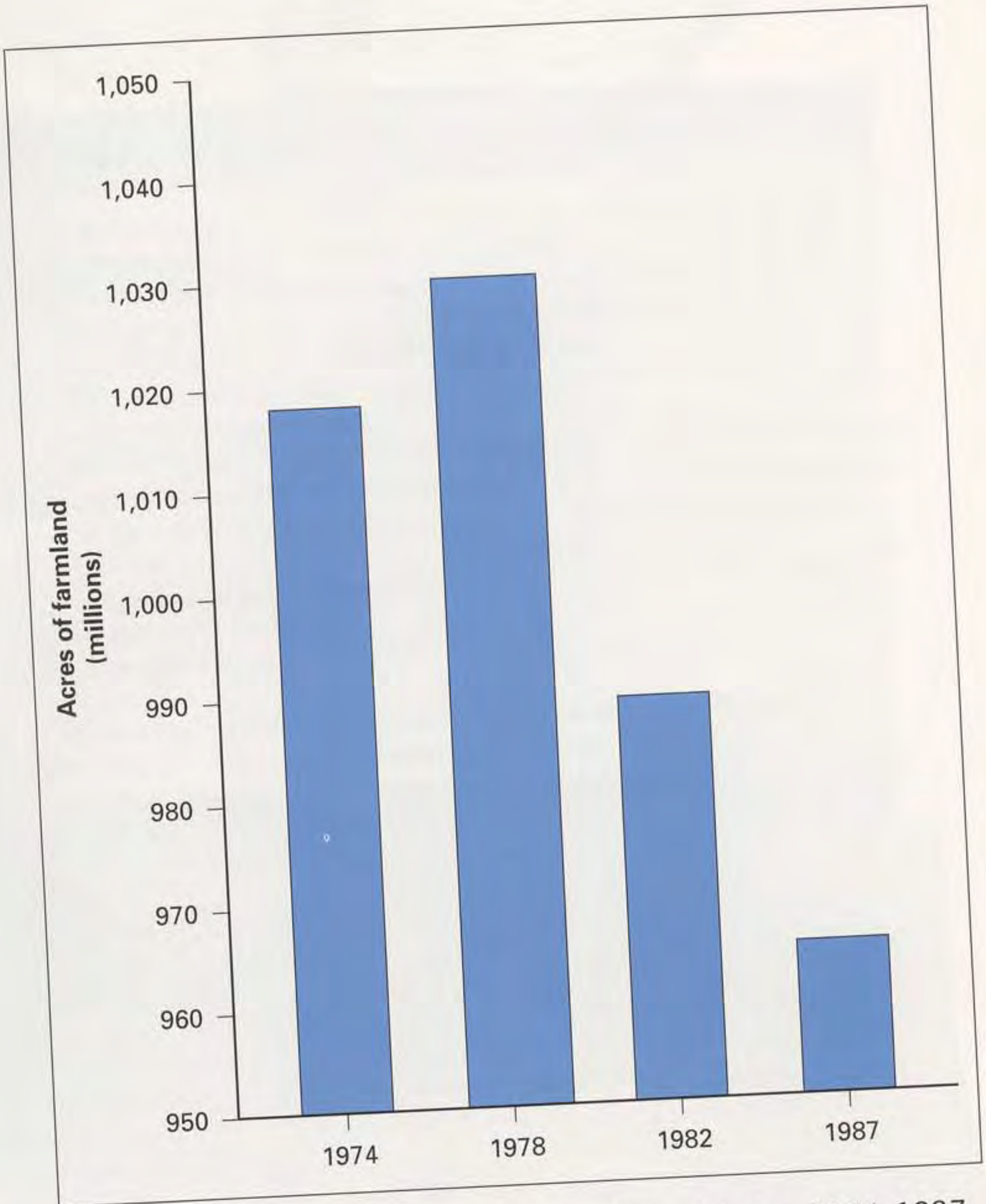


Figure 13 Total acreage of farmland in the United States, 1974–1987.

Sources: U.S. Department of Commerce, Bureau of the Census, *1978 Census of Agriculture* and *1987 Census of Agriculture.*

Why did farmers begin increasing the amount of land under cultivation after 1974 (Figure 13 on page 48)? Why were fewer acres under cultivation in 1987 than in 1978?

Table 8 below is a time line of important events in U.S. agriculture since the 1930s. During this period, U.S. government policies have encouraged many farmers to produce only certain crops. Other events, outside of the United States, have also influenced choices that U.S. farmers have made about what crops to raise.

Table 8 Major changes in U.S. agriculture since 1933

1933—U.S. government begins price supports	U.S. government began paying farmers to produce food crops needed to help combat the Depression. The government wanted to keep farmers in business to provide food for the jobless and homeless. Farmers concentrated on raising crops that were subsidized. The most important crops were corn, soybeans, and wheat.
1939–1945—Higher use of chemicals begins during World War II	Farmers answered the demand for more food by relying more on petroleum-based fertilizers, herbicides, and pesticides.
1950—World demand for food increases rapidly	World population was growing rapidly. U.S. farmers responded by increasing the use of chemicals to produce more food. They also increased the acreage in cultivation.
1973—OPEC oil embargo	When oil prices rose, developing countries could not afford petroleum-based chemicals. This meant only wealthy countries could afford chemicals that helped grow large amounts of food, so less food was grown. Growing populations and reduced food supplies drove food prices up worldwide. In the United States, farmers responded by growing more food. Dry lands in the West, which required expensive irrigation, were cultivated. This land, when plowed, became prone to erosion. These factors also drove the price of food up.
1985—Farm Bill of 1985	Congress began to remove price supports for farmers. Many acres were removed from cultivation. U.S. reliance on costly petroleum-based chemicals and fuels began making crops too expensive to compete on international and domestic markets.
1988—Drought in North America	Decreased acreage and drought meant a huge drop in production. Many small farms went bankrupt.

Sources: Brown 1989; Sass 1990.

4. Why did the U.S. government want to pay farmers to grow food during the Depression? Why did these policies encourage monocropping?
5. Why did farmers rely so much on chemical-based fertilizers beginning in 1950?
6. Why did the acreage under production increase after 1974?
7. What problems have occurred from increased production on arid and semiarid lands in the West?
8. Why did the acreage under cultivation decrease in the 1980s?
9. What were some economic and social effects of the 1988 drought on farmers?

Is sustainable farming in the United States affordable?

Policies encouraging farmers to use marginal lands to produce more food may lead to long-term damage to soil and water resources in the West. But policies that lead to overproduction are not only unsustainable for the environment; they also do not make good economic sense. If too much food is produced in a given year, prices may fall. So the farmer's income also drops. To be truly sustainable, farming must conserve the environment and produce enough food, but it must also provide enough income so the farmer can make a living.

Do sustainable farming methods make better economic sense? The following is a description of two farms in the United States. Mr. Jones's farm uses conventional methods common in U.S. agriculture. Mrs. Martinez's farm uses several alternative, sustainable methods.

Jones farm

Mr. Jones's farm uses conventional methods to grow crops that the U.S. government guarantees will have a minimum price. Mostly he grows corn, wheat, and soybeans.

Mr. Jones has most of his farm devoted to monocropping. He can raise the crop for which he gets the most money. He uses petroleum-based fertilizer to keep the soil fertile.

Because only one crop is grown in a field at a time, it is especially vulnerable to being completely wiped out by insect pests that feed on that plant. Mr. Jones relies on chemical pesticides to control insects. Weeds are controlled by chemical herbicides. These are sprayed on the fields periodically throughout the year.

Plowing is done in long rows because it is most efficient for the large tractors. This method requires less fuel for the large machines than plowing along the slope contours. After crops are harvested the soil is left barren. Snows are expected to cover the soil to prevent erosion.

Mr. Jones plows and disks the soil in the spring to retain moisture. Even so, he almost went broke in the drought of 1988. He now has drilled several wells to obtain groundwater for irrigation water so that another drought won't affect him as much.

All machines on the farm, and Mr. Jones's farmhouse and barn, use petroleum-based energy.

Martinez farm

Mrs. Martinez uses a seven-crop rotation every year. Each year four crops are cash crops, such as wheat and corn. If the price for one crop is down, she can make money on the others. The other three crops are legumes that fix nitrogen. She uses these crops to replace nutrients in the soil used by her other crops. That way she does not have to rely on chemical fertilizers.

Instead of spraying weeds with herbicides, Mrs. Martinez removes them by mechanical means. She controls pests by using their natural enemies, such as ladybugs. These attack many insects that are harmful to crops.

Mrs. Martinez also uses nitrogen-fixing crops, such as alfalfa, to feed livestock. She uses livestock manure to help fertilize fields. She also uses livestock to help control weeds by allowing them to graze in the fields at certain times of the year.

When Mrs. Martinez harvests a crop, she never cuts down harvested plants. Instead she allows them to stay in the ground to prevent erosion of barren soil. They also serve as fodder. To aid in holding the soil, Mrs. Martinez raises perennials in alternating rows with her crops. The perennials are also a cash crop.

Each year, Mrs. Martinez plows her nitrogen crops under. This keeps the soil soft and crumbly so it can more easily store water and air. Mrs. Martinez was able to survive 1988's drought because her soil was able to hold enough water to nourish the plants without irrigation.

Mrs. Martinez uses solar and wind power on her farm whenever possible. She uses smaller tractors that use less fuel and are easy to maneuver. Therefore, she can plow following the contours of the land to prevent erosion more effectively.

The Martinez farm's methods provide several environmental benefits. But can the U.S. farmer make money using sustainable methods like these?

To determine if sustainable agriculture can be profitable, look at these statistics from two different farms (Table 9 on page 53). Remember that this cost analysis is only in terms of money. It does not take into account environmental damage, human costs, or long-range gains or losses. It simply shows whether farming as a business can use sustainable methods.

In Table 9, "Total input costs" is the sum of all farming costs, including fuel for machinery, seed for crops, fertilizers, and labor. "Total cash income" is the amount made by the farmer when the crops are sold. The difference between costs and income is the profit (per acre), shown here in the "Net cash profits" column.

Only about 3 percent of U.S. farms currently use sustainable methods. But the number is increasing. In 1980 only about 1 percent of farms in the United States used sustainable practices (Reganold et al. 1990).

Do you think that more farmers should shift to sustainable agriculture? How can this practice be encouraged?

Table 9 Cost analysis of conventional and sustainable farms (dollars per acre)

	Total input costs	Total cash income	Net cash profits
Conventional Methods	53	92	39
Sustainable Methods	44	91	47

Source: Reganold et al. 1990.

10. What is the difference in profit per acre between the two types of farming?
11. What would the difference in profits be if both farms had 1,500 acres?
12. What category is most important in accounting for the difference in net cash profits?
13. Why are costs on a sustainable farm lower than on a conventional farm? (You may want to look back at the descriptions of the Jones and Martinez farms.)
14. What do you think the "Total input costs" column would look like if environmental costs, such as loss of soil and groundwater resources, were figured in? Why?

Lesson 8

How can world agriculture be made sustainable?

Objective

In this lesson, you will

- Develop a strategy for promoting sustainable agriculture around the world.

Glossary Words

marginal land
soil

A review: 10 problems with world agriculture

1. To feed the world's growing population, more food is needed.
2. Agricultural productivity has increased tremendously in the last 40 years. Most of this increase is from heavy use of petroleum-based fertilizers.
3. The countries where most of the world's people live are growing the fastest, but they are usually too poor to afford petroleum-based fertilizers.
4. Food productivity in industrial countries is already near the biological maximum—that is, as much as the plants themselves can produce.
5. Mechanization of farms has reduced the need for farm labor. Many farmers have migrated to cities, increasing urban growth.

6. There is limited land available to increase farm production. This is especially true in some poorer countries.
7. Soil erosion and depletion of water resources have turned many marginal lands into deserts (especially in Africa and Asia).
8. Tropical soils have limited agricultural potential. Special methods are needed to maintain their fertility.
9. Food crops adapted to fertile soils may not be suitable for harsh, marginal lands. Crops suited to dry or infertile soils are needed for such areas.
10. Some traditional farming methods, used for thousands of years by people around the world, are more ecologically sustainable than modern methods.

In this lesson, you will develop a possible solution to these problems of agriculture. Any solution must fit different situations in all countries. This requires that you look at the problem in a global perspective. We can classify countries into two types: more-developed countries and less-developed countries. Each has different agricultural problems (Oram 1989).

More-developed countries rely on mechanical and chemical means to produce great amounts of food. As you have seen, these methods may in turn pollute water resources, erode soil, and deplete fossil fuels. Is this type of agriculture sustainable?

Less-developed countries use more traditional methods of cultivation. They rely heavily on human and animal power. They produce small amounts of food, although they have great population growth. This growth causes people to cut down forests and plant on marginal lands. They cannot afford the mechanical and chemical means of more-developed countries. Is this type of agriculture sustainable?

It is easy to see that world agriculture is in trouble. What solutions, if any, can and should be applied?

Glossary

Agricultural system The methods and purposes for growing certain crops, including all of the inputs used to grow the crop and the outputs that result, such as whether the crop is grown for export or for the domestic market.

Agroforestry A farming system that combines row crops with certain kinds of trees to sustain forest and soil resources.

Aquifer A layer of rock that holds and readily transmits groundwater.

Arable land Land that is suitable for agriculture.

Cash crops Farm products grown for the purpose of being sold.

Commercial agriculture Farming for the purpose of producing surplus crops, which are then sold. Proceeds are used to buy goods needed by the farmer and his or her family.

Domestication The act of breeding and training animals and plants to be of use to humans.

Doubling time The number of years for a population to double, if the rate of increasing population stays the same during the doubling-time period.

East Malaysia In this module, the term refers to the Malaysian states of Sabah and Sarawak, on the island of Borneo.

Ecosystem A natural system in which energy moves through plants, animals, and microorganisms in a complex web of relationships. For example, using energy from the sun, plants derive nutrients from soil. Animals eat plants to get the nutrients. Microorganisms decompose dead animals and plants, returning the nutrients to soil.

Fallow Farmland on which no crops are planted for a period of time. Farmers leave land fallow to improve the soil's fertility for future use.

Fodder Feed for livestock, often consisting of stalks and leaves of corn mixed with other plants, such as hay.

Hectare A metric unit of area equal to 2.47 acres.

Herbicide A chemical used by farmers and gardeners to kill unwanted plants (weeds).

Humus Decaying and decomposed organic matter produced by the actions of microorganisms (algae, fungi, and bacteria) found in the top layers of soil. The amount of humus in soil is an important factor in soil fertility.

Leaching The washing away of essential plant nutrients through the soil. Leaching lowers soil fertility.

Legumes A family of plants (including alfalfa, peas, and beans) that can take nitrogen from the air and convert it to a form usable by other plants. This increases soil fertility. Farmers often grow legumes and plow them under as a fertilizer.

Manuring The spreading of animal manure on fields as a fertilizer.

Marginal land Land (too dry, too wet, or too steep) with a low suitability for nourishing crops or livestock. Marginal land can be easily damaged by agriculture.

Monocropping Growing a single crop year after year in the same field. This depletes soil fertility unless essential plant nutrients are replaced.

Monsoon Seasonal winds of the equatorial zones. In the wet season they pick up moisture from the oceans and release it over land. Monsoons usually have periods of heavy rains followed by dry seasons in which no rain occurs.

Nitrogen fixation The process in which bacteria and other soil microorganisms living on the roots of certain plants (such as legumes) convert atmospheric nitrogen into nitrates, nutrients needed by other growing plants. See **legumes.**

Nutrient cycling All methods and purposes for growing certain crops, including all of the "inputs" used to grow the crop and the "outputs" that result, such as whether the crop is grown for export or for the domestic market.

Nonrenewable resource A resource that is used up faster than its renewal or replacement by natural processes.

Pesticide A chemical used to kill unwanted animals or insects that destroy crops or livestock.

Plant nutrients Minerals (such as potassium, nitrogen, and phosphorus) essential for plant growth.

Renewable resource A resource that is used more slowly than its renewal or replacement by natural processes.

Soil The loose material on Earth's surface, consisting of varying amounts of organic matter (humus), minerals (sand, silt, clay, and plant nutrients), and pores (filled with water or air). See **humus, plant nutrients.**

Soil fertility The measure of how abundant plant nutrients are in a soil.

Subsistence agriculture Farming or livestock raising that produces only enough to sustain the farmer and his or her family.

Topsoil Name given to the uppermost layer of soil. In the midlatitudes, such as the United States, topsoil is rich in humus and other plant nutrients. See **humus, plant nutrients, soil.**

West Malaysia Term used to refer to Malaysia's territory on the Malay Peninsula, on mainland Southeast Asia. Also known as *Malaya or Peninsular Malaysia.*

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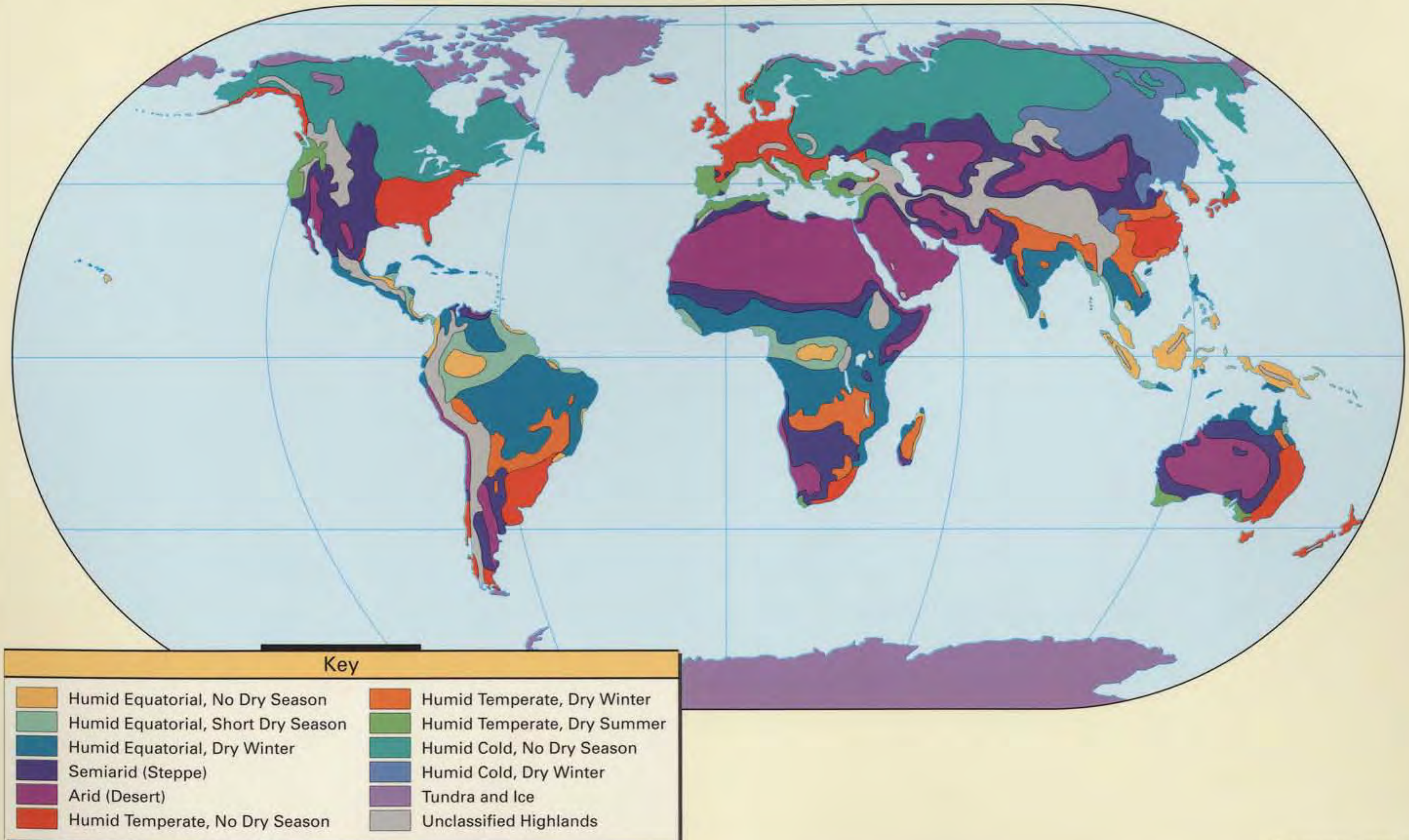
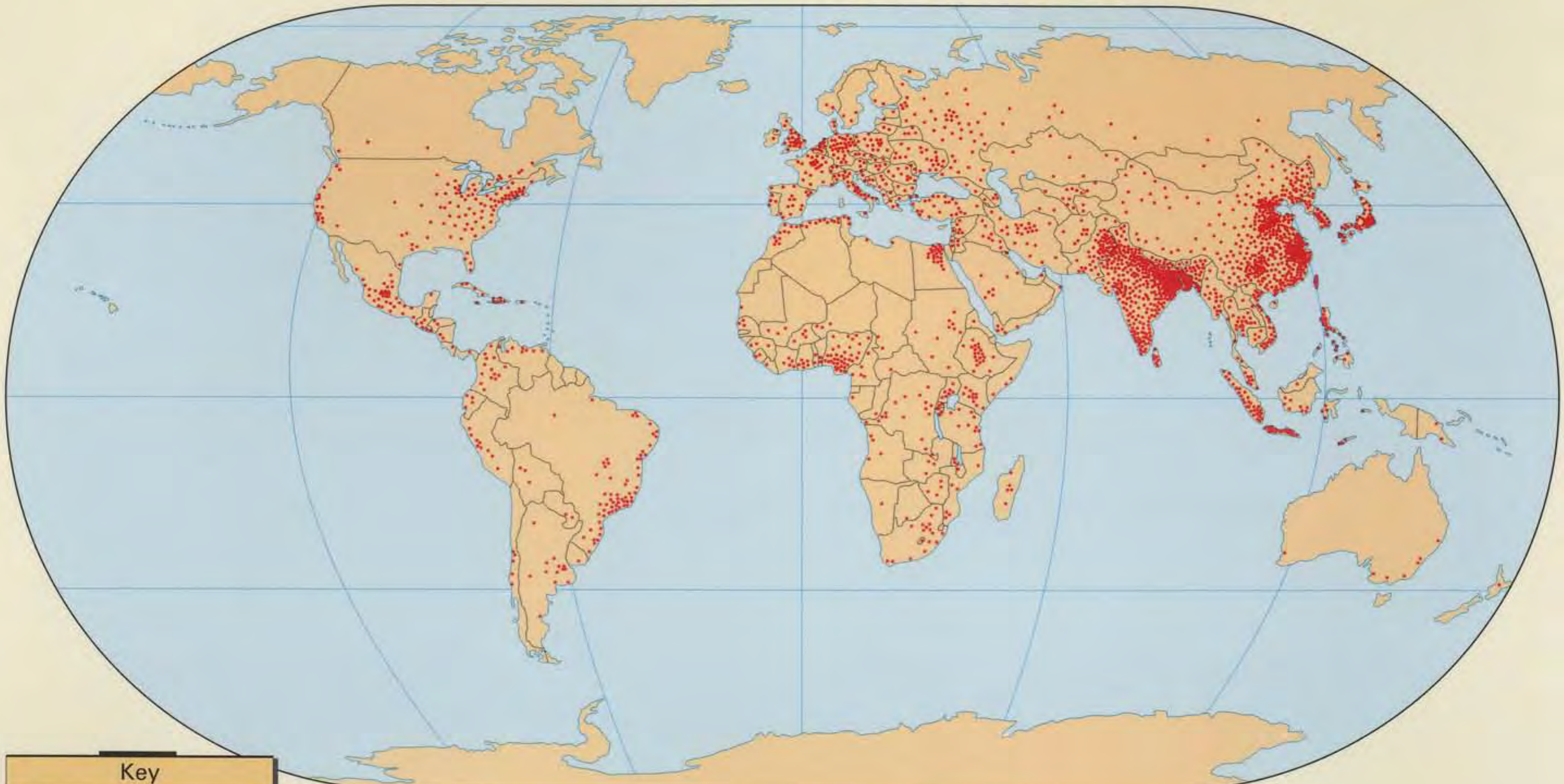
Map 1

CLIMATES OF THE WORLD



Map 2

WORLD POPULATION DISTRIBUTION



Key

One dot represents approximately 2,500,000 people.

Source: Britannica World Data Annual (1994)

Map 3

WORLD DISTRIBUTION OF GRAIN PRODUCTION

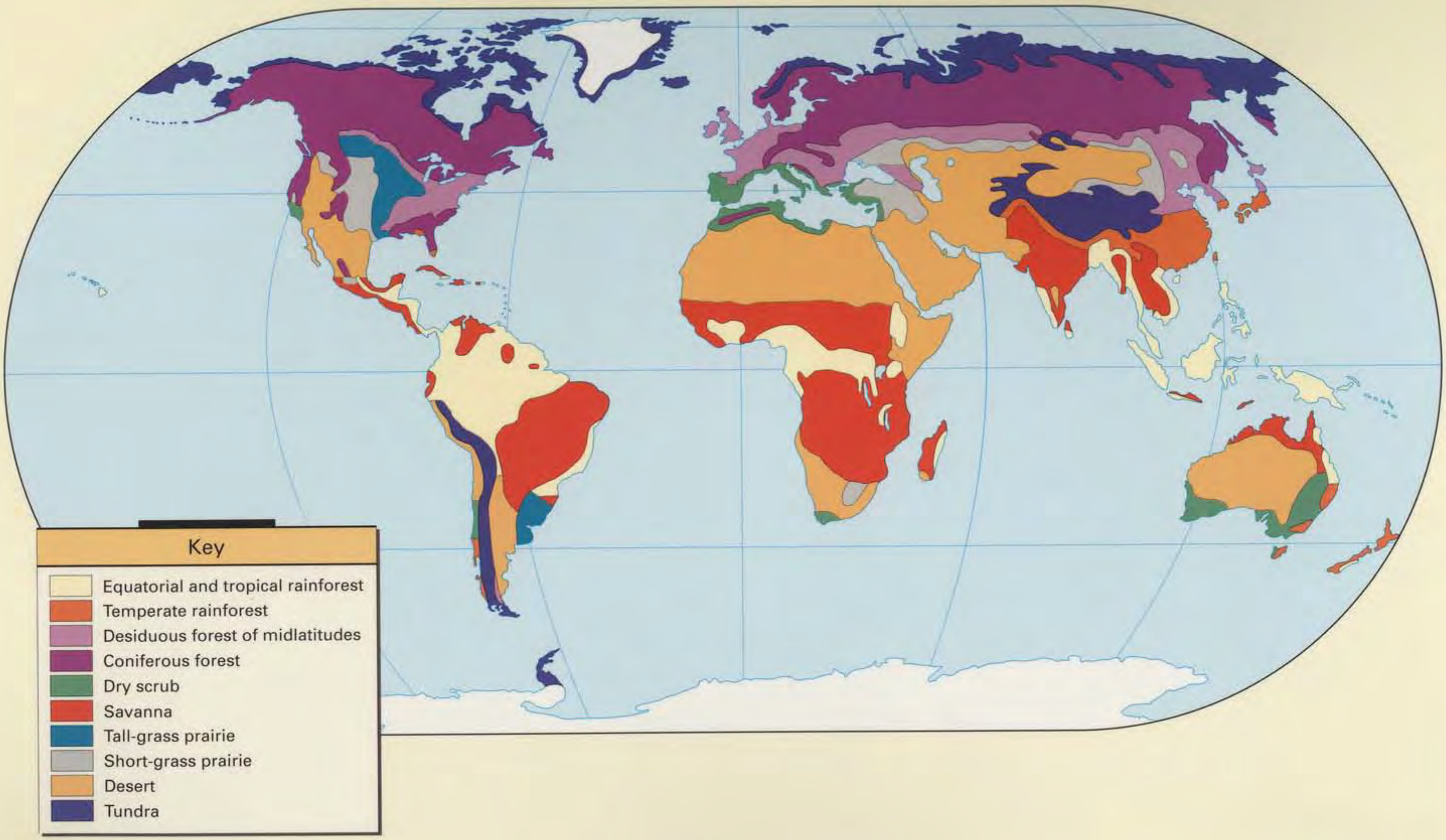
Key

Rice	Corn	Wheat	Metric tons produced annually
●	▲	■	More than 100,000,000
●	▲	■	50,000,000-100,000,000
●	▲	■	15,000,000-50,000,000
●	▲	■	5,000,000-15,000,000
		▭	No data

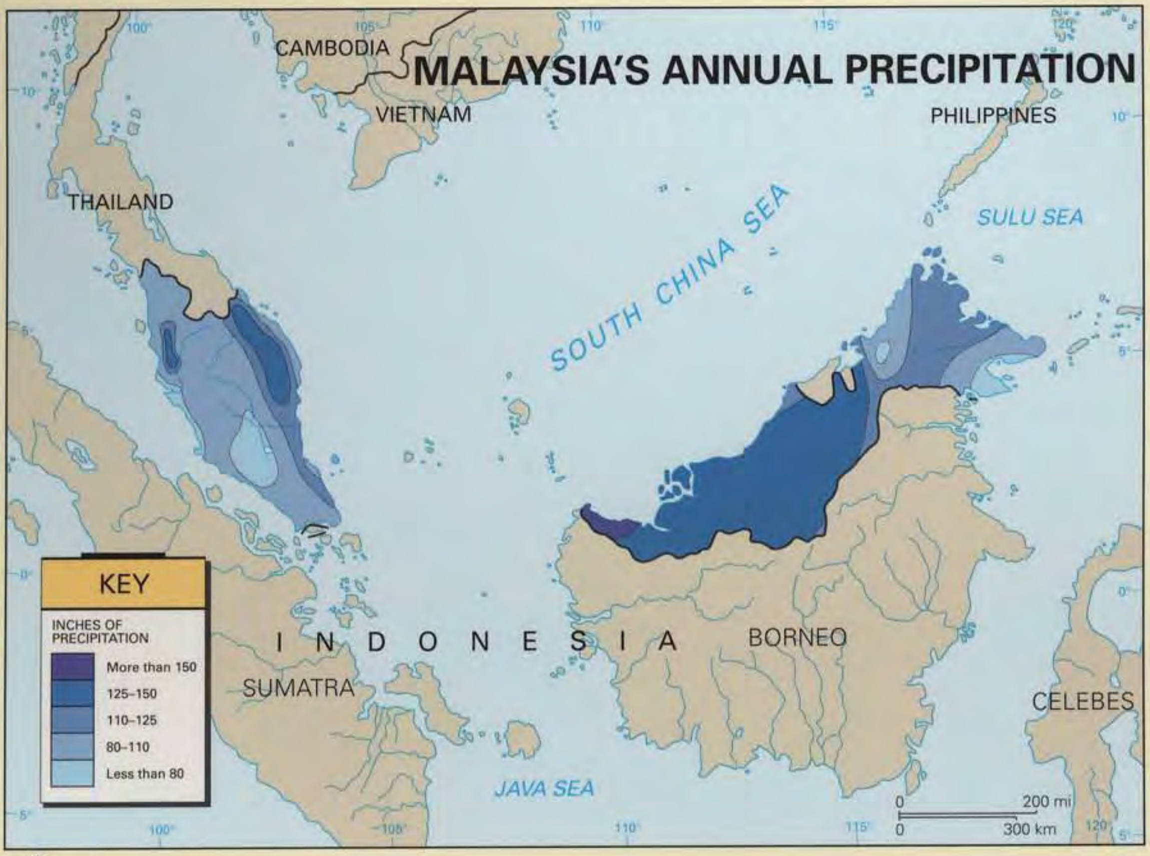
Data Source: FAO Production Yearbook (1991)

Map 4

WORLD VEGETATION



Map 5


MALAYSIA'S ANNUAL PRECIPITATION
CAMBODIA
VIETNAM
PHILIPPINES
THAILAND
SOUTH CHINA SEA
SULU SEA
I N D O N E S I A
SUMATRA
BORNEO
CELEBES
JAVA SEA
KEY
INCHES OF PRECIPITATION
More than 150
125–150
110–125
80–110
Less than 80
0 200 mi
0 300 km
100°
105°
110°
115°
120°
10°
5°
0°

Map 6


MALAYSIA'S PHYSICAL FEATURES
CAMBODIA
Gulf of Thailand
VIETNAM
PHILIPPINES
THAILAND
MALAY PENINSULA
SOUTH CHINA SEA
SULU SEA
LANGKAWI ISLAND
Kangar
Alor Setar
Butterworth
George Town
PENANG ISLAND
Kota Baharu
Kuala Terengganu
Taiping
Ipoh
Kampar
Kuala Lipis
Kuala Dungun
Teluk Intan
Kuantan
(WEST MALAYSIA)
Bentong
Petaling Jaya
Kuala Lumpur
Kelang
Port Dickson
TIOMAN ISLAND
Segamat
Mersing
Melaka
Muar
Keluang
Batu Pahat
Kota Tinggi
Pontian Kechil
Johor Baharu
SINGAPORE
CAMERON HIGHLANDS
M A L A Y S I A
Kota Kinabalu
Mount Kinabalu 4101
Sandakan
LABUAN ISLAND
BRUNEI
Victoria
SABAH
Darvel Peninsula
Kuala Belait
Miri
Tawau
(EAST MALAYSIA)
Mount Murud 2423
SARAWAK
Batu Hill 2011
Sibu
Sarikei
Kuching
I N D O N E S I A
SUMATRA
BORNEO
KEY
International boundaries
State boundaries for East Malaysia
Capitals
Cities
Elevation
metres
feet
1000
3281
500
1640
200
656
0 200 mi
0 300 km
100°
105°
110°
115°
120°
10°
5°
0°

Map 7


LAND USE OF MALAYSIA
CAMBODIA
VIETNAM
THAILAND
PHILIPPINES
SULU SEA
SOUTH CHINA SEA
MALAYSIA
INDONESIA
SUMATRA
BORNEO
CELEBES
JAVA SEA
KEY
International boundaries
Rice
Rubber and rice
Rubber and oil palms
Equatorial rainforest
100°
105°
110°
115°
120°
10°
5°
0°
-5°